4

The Macmillan Science Series

Science for Tomorrow's World

Teachers' Annotated Edition

THE MACMILLAN SCIENCE SERIES
FOR ELEMENTARY SCHOOLS

A NINE-BOOK SERIES

SCIENCE FOR TOMORROW'S WORLD, BOOK 4

YOUR TEACHERS' ANNOTATED EDITION PROVIDES:

- *A Teachers' Guide, bound into the back of the textbook*

  The Content and Process of Science Education (see guide pages 7 to 22)—This overview of science education in today's elementary schools explains the philosophy behind THE MACMILLAN SCIENCE SERIES, with emphasis on the *structure of subject matter* in the science curriculum and the *conceptual framework* of the series.

  How Children Acquire Science Knowledge: A Developmental Approach (see guide pages 23 to 31)—Here is a practical discussion of the relationship between the teaching of science and the development of logical thought processes.

  Some Problems of Method in Teaching Science (see guide pages 32 to 61)—This part of the guide covers such important topics as providing for individual differences and using community resources.

  Overviews, Tests, and Directories (see guide page 62)—Here are overviews for each unit in the book plus the table of contents of each book in the SCIENCE FOR TOMORROW'S WORLD, BOOKS 1-6, series to appraise you of the place of your book in the series structure. This section also includes tests for each unit in the textbook and directories of publishers, film and filmstrip sources, and suppliers of source materials.

- *The Pupils' Textbook, with teaching suggestions printed beside the text pages and with annotations printed right on the text pages*

  Fully developed lesson plans | Background information | Additional activities and demonstrations | Readings for the pupils and the teacher | Answers to the questions in the textbook | Checklist of science materials

An activity suggested on page 197 of the text.

SOME OF THE SPECIAL FEATURES YOU'LL FIND IN BOOK 4:

Units organized to teach the Key Concepts of science

SCIENCE FOR TOMORROW'S WORLD, BOOK 4, is built on the 10 Key Concepts of science that are described on pages 12—18 in the Teachers' Guide.

Throughout the text, specific concepts lead the pupils toward deeper understanding of these Key Concepts. Unit 5, for example, helps pupils to understand:

The Key Concepts

All objects in the universe and all particles of matter are constantly in motion; man has discovered and stated the laws governing their motion.

The motion of particles helps to explain such phenomena as heat, light, electricity, magnetism, and chemical change.

The Specific Concepts

1. All matter is composed of atoms which in turn are made up of electrons, protons, and neutrons (pages 141-143, 166-168).

2. Like electric charges repel each other; unlike electric charges attract each other (pages 144-147, 166-168).

3. The force of electric charges decreases with an increase in distance (pages 146-147).

4. An electric current is a flow of electrons (pages 148-158, 166-167).

5. An electric current can produce a magnetic field; a magnetic field is a force that can produce motion (pages 159-160, 166).

6. Electricity is safe to use, if used wisely (pages 140, 159-165, 167-169).

Lessons, activities, and illustrations that teach pupils to think and work using the ways of the scientist

SCIENCE FOR TOMORROW'S WORLD, BOOK 4, provides numerous insights into the ways in which scientists think and work. Unit 1, for example, teaches the pupils to work out problems by:

Questioning (pages 2, 5-8, 12, 14, 16-17)
Observing (pages 2-3, 5-7, 9-10, 12-13, 16-18)
Experimenting (pages 2, 5-12, 14-19)
Comparing (see entire unit!)
Inferring (pages 8, 9, 11)
Measuring (pages 2, 4-6, 9-12, 14-17)
Selecting sources of information (pages 4, 5-7, 12-15, 19)
Communicating (pages 2, 12-13, 16-19)
Explaining (pages 5-7, 9-10, 12, 16-19)
Hypothesizing or speculating (pages 6, 11-12, 15)

For more special features, turn to the inside back cover.

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TEACHERS' ANNOTATED EDITION

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SCIENCE FOR TOMORROW'S WORLD: 1, 2, 3, 4, 5, 6
SCIENCE: A SEARCH FOR EVIDENCE 7
SCIENCE: A WAY TO SOLVE PROBLEMS 8
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Texts, Teachers' Annotated Editions, and other Complementary and Supplementary Teaching Materials

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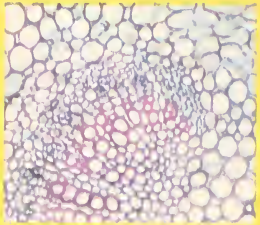
The TEACHERS' ANNOTATED EDITION consists of

- Teaching Suggestions
- Annotated text pages
- Teachers' Guide



THE MACMILLAN SCIENCE SERIES

Science for Tomorrow's World

4

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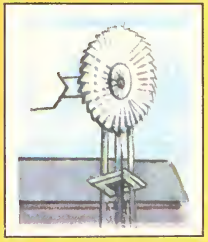

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ABOUT THE TEACHING SUGGESTIONS

Teaching Suggestions, for each page in the pupil's textbook, are found on the outside of the page. The Teaching Suggestions include lesson plans, background material, the answers to the questions posed in the pupil's pages, additional activities, and bibliographies of books and films. The suggestions apply directly to the material on the pupil's pages and provide a ready reference for the teacher as he or she uses the textbook in class. Many pages have space on them for teachers to write in their own comments. A Materials Checklist is included in each book, containing ample space for teachers to add materials for experiments and demonstrations of their own.

PROFESSIONAL BOOKS FOR TEACHERS

Blough, Glenn O., *It's Time for Better Elementary School Science.* NSTA, 1958. 48 pp. Of special interest to administrators and supervisors. Theory for science curriculum construction.

Brandwein, Paul F., Fletcher G. Watson, and Paul E. Blackwood. *A Book of Methods.* New York: Harcourt, Brace, 1958. 568 pp. An excellent sourcebook.

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Stendler, Celia B., *Teaching in the Elementary School.* New York: Harcourt, Brace, 1958.

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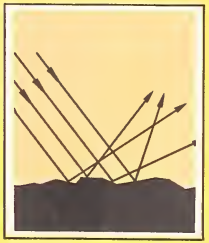

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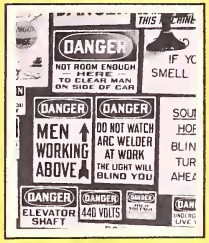

California Journal of Elementary Education, Vol. 21, No. 2, November 1952. 63 pp. Special issue on science for every child and every teacher; characteristics of a good program, equipment, and materials.

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Looking Ahead in Science. California State Department of Education, 1960. 88 pp. Report of the Production Seminar and Conferences on the Improvement of Science Education in the Elementary School Purposes, appropriate experiences and content, equipment and materials, scheduling, evaluation, pre- and in-service education.

Safety Through Elementary Science. Washington, D.C.: National Education Association, 1949.

Theory Into Action. NSTA, 1964. 48 pp. Discusses science curriculum development based on conceptual schemes.

UNESCO: Source Book for Science Teaching. New York: UNESCO, 1959. This volume has been revised, expanded, and reprinted in many editions.

KEY CONCEPTS

Key Concept 1. Events in the natural environment happen in an orderly rather than a haphazard way; man searches for laws to explain this order by observing, hypothesizing, checking his ideas, and rejecting those which do not square with reality.

Key Concept 9. The scientist has developed measures of space, time, and matter so that he can communicate explanations that are reproducible and make predictions about events in the natural environment.

CONCEPTS:

1. One way in which scientists find out about things is by making comparisons. In doing this they measure various attributes. They use instruments to measure.
2. Experiments are done to test ideas or hypotheses.
3. Ideas regarding the motion of falling bodies have been tested by experiments.

The Scientist's Way

1

Other concepts appear under "Learnings to Be Developed" in each lesson found in the Teaching Suggestions.

Comparing Things

Making Comparisons to Find Answers

The ability to observe a reaction, such as the one occurring to the liquid in this test tube, is an important way of the scientist.

PROCESSES:

- Questioning—Page 6.
- Observing—2, 8, 9.
- Experimenting—8, 9, 14, 15.
- Comparing—2, 8, 9, 14.
- Inferring—8, 9, 11.
- Measuring—8, 9, 14.
- Classifying—2.
- Selection (sources from recall)—2, 3, 7, 12, 14, 19.
- Communicating—2, 16, 17, 18.
- Explaining—7, 9, 11, 14.
- Hypothesizing or Speculating—11, 15.

TEACHING SUGGESTIONS
(pp. 2–3)

● **LESSON:** What is a comparison?

Background: In this introductory unit, youngsters are introduced to experimental methods through a series of problems and historical incidents.

Learnings to Be Developed:

One way in which the scientist finds out about things is by making comparisons.

Scientists use instruments for measuring.

Developing the Lesson: Ask the children in one row to stand up. Ask all but the tallest boy in the row to sit down. Repeat with each row of children.

- *Who is the tallest boy in the class?*
- *How can we tell?* (By comparing.)

Measure the height with a ruler.

- *Can we make our own instruments?*

Children can use string units to measure length and a paper clip or a penny to measure weight.

To demonstrate the need for measurement, flash on a screen, or draw on the chalkboard, two lines of equal length which ap-

The scientists on the opposite page are comparing things. So are the boys and girls. When you compare things, you show the ways in which things are like each other and the ways in which they are different. When you looked at the pictures, you compared something. Do you know what you compared?

Making Comparisons to Find Answers

A scientific **comparison** is a way of telling how things are alike and how they are different. One way the scientist finds out about things is by making comparisons.

Look again at the pictures of the scientists. Some are using special tools. These special tools of scientists are called **instruments**. Can you name some of their instruments? Do you know why scientists use these instruments? Do you ever use any instruments to help you compare things? Why do you use them? Do you see any of these instruments in the pictures of boys and girls comparing things?

What Do You Compare?

You compare many things. You compare how tall you are today with how tall you were a year ago. You compare how much you weigh today with how much you weighed last year. What else do you compare?

You get answers to many of your questions by comparing things. Scientists get answers to many of their questions by comparing things. They compare things by weighing them, timing them, testing them, and measuring them. These are some of the ways of scientists. The scientists write down everything they learn about the things they are comparing. It is always important to keep records.

When scientists do **experiments**, they make comparisons. They do experiments to find the answers to many of their questions. But there was a time when many people would not think of doing experiments to find the answers. Instead, they depended on the ideas

pear to be unequal because of an optical illusion (arrow heads pointing away from each other on one line, toward each other on the other line).

- *Which line is longer?*
- *How can we find out?*

Obtain two jars of different shapes.

- *Which jar will hold more water?*
- *How can we find out?*

Fill one jar with water; then pour water from that jar into the other.

Have pupils study the pictures and tell what scientists and children are comparing in each.

Follow-Up: Ask pupils to write down the names of the instruments they would need to answer the following questions:

- *Is it hotter near the door or near the window?*
- *Is a glassful of air heavier than a glassful of water?*
- *Can boys run faster than girls?*
- *Which is the thickest book on the teacher's desk?*

Now ask them to write about the kind of experiments they would need to do in order to answer the questions. Save their answers to compare with work done at the end of the unit.

WAYS OF COMPARING THINGS

TEACHING SUGGESTIONS
(pp. 4–5)

LESSON: How did Galileo help to develop the methods used by today's scientists?

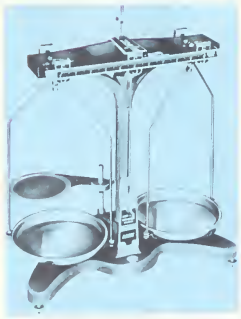
Background: What *is* the scientific method? One famous scientist said the scientific method is nothing more than doing the most with one's mind, "no holds barred." Galileo did this magnificently, and he is rightly called the father of experimental science.

Learnings to Be Developed: Galileo sought proof of his findings by making many comparisons and measurements.

Developing the Lesson: After a brief discussion of the historical implications of Galileo's work and his constant search for tests to assure himself of his findings, ask the following questions:

- *If you wanted to find out whether one ball point pen was better than another, how would you find out?*

The scribble test for longevity, the ability to write on all surfaces, mechanical construction, variations under changing weather, etc., all become part of the testing procedure. At this point, the idea of what to test for should be introduced. Refer the children to



These are some of the tools of scientists. What might the scale and timer be used to compare? How might the test tubes be used to make a comparison?

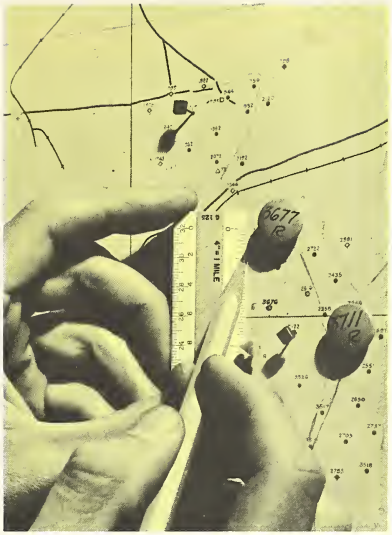
of wise men to give them the answers to their questions.

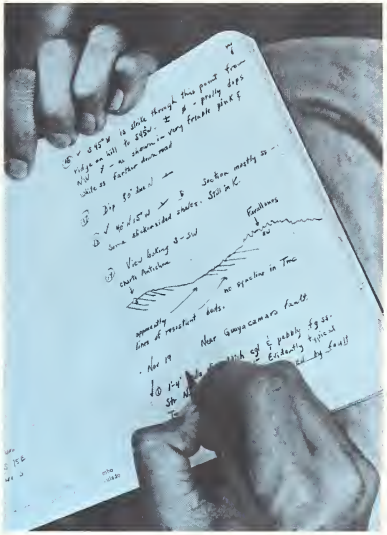
Aristotle (AR-iss-tot'l) was the most famous of these wise men. He lived in Greece over 2,000 years ago. Aristotle's ideas were thought to be the truth. For a long time, very few people ever questioned his ideas. People thought that ideas that everyone had believed for such a long time must be true.

Galileo Seeks Proof

Galileo Galilei (gal-uh-LAY-oh gal-uh-LAY-ee), born in Pisa, Italy, in 1564, helped change many of the ideas that people had believed for a long time.

Today, Galileo is remembered as one of the first scientists to seek proof for his ideas. He did not believe in accepting something as true just because Aristotle had said it was true.





What are the scientists doing in these two pictures? What ways of making comparisons are shown? Why is it important for scientists to keep accurate records of their work?

Galileo was an observing man, and he asked many questions about what he observed. Sometimes what he observed did not agree with what Aristotle had said was true. Then Galileo set about finding proof.

To find the answers to his questions, Galileo measured, weighed, and timed things. He believed in trying not once or twice, but many times, until there could be no doubt about his answers. He compared what actually happened in his experiments with what he thought might happen. For example, he figured out where a cannon ball would land when fired from the mouth of a cannon. After the cannon ball landed, Galileo checked his figures.

Galileo questioned the scientific ideas he heard and read about. He was always asking "how" questions. Most of the time, the only answers

the pictures on pages 3, 4, and 5 and ask:

- *Galileo measured distance on the cannon ball flight. What can we measure in making tests?*

The various pictures on pages 4 and 5 give indications of time, length, volume, color, weight, heat, and distance.

Background: The following material will provide you with background information for the questions posed by the captions on pages 4 and 5.

The scale illustrated is used to compare the weight of an unknown object with a known weight. It is also used to compare the weight of a single object in and out of water.

The timer could be used to compare the time it takes various substances to dissolve in water.

The test tubes could be used to compare changes in color or temperature of two chemical reactions.

Land measurements (comparisons with a scale) are being made on a map, and records are being kept in a field manual.

The data being recorded are needed before judgments or hypotheses can be tested.

TEACHING SUGGESTIONS
(pp. 6–7)

LESSON: What properties of the swinging lamp did Galileo compare?

Background: Galileo's laws of the pendulum served as a basis for later work on gravity and acceleration. The swinging lamp is an example of a pendulum.

Learnings to Be Developed: Time and distance were two properties that Galileo compared.

Developing the Lesson: To begin this lesson, suspend a basketball or volleyball from the ceiling near the front of the room. Set it in motion and ask the children:

What are we all doing now?

The answers will probably center around the idea that they are *looking* at the swinging ball.

What would a scientist call this "looking"?

Here you are after the word *observing*. Emphasize the fact that observation is the first step in any scientific gathering of data, and that a good scientist keeps his observations in mind.

Observation helps us recognize people.

Galileo got to his questions were, "This is the way it has always been done," and "It is not for you to ask *how*."

Answers such as these made Galileo want to find out all the more. One of the things he was most interested in was *how* things fall to the earth. Aristotle also had been interested in falling objects, but Aristotle had only asked *why* things fall to the earth.

Galileo believed that anyone who asked *why* things fall to the earth got the wrong answers. He got "because" answers, like Aristotle's. Aristotle had said that things fall to the earth *because* they are heavy. They go toward their natural place, which is the earth, said Aristotle, *because* the earth is the heaviest of all things. Heavy things fall faster than light things *because* they have more power to seek the earth.

But suppose you ask, as Galileo did, "*How* do things fall to the earth?" If you are going to find out *how*, then you must ask:

How far does the thing fall?
How long does it take to fall?
Does it speed up as it falls?

If you want to know whether heavy things fall faster than light things, there is one more question to ask. What is the question?

To find answers to his questions, Galileo measured things. Then, using his measurements, he tried to guess what results he would get if he did certain experiments.

The Swinging Lamp

A story is told that one day, while in the cathedral of Pisa, Galileo watched some workmen busily making repairs to the roof. Their hammering caused a lamp hanging from the ceiling to swing back and forth. Suddenly, Galileo found himself watching the lamp. As he watched, he asked himself such questions as:

1. Does each swing of the lamp take the same amount of time?
2. Does the lamp swing as high to one side as it does to the other side?
3. Suppose the chain holding the lamp were shortened or lengthened. Would that make any difference in the time it would take the lamp to swing back and forth?
4. Suppose a heavier or lighter lamp were used. Would that make any difference in the time it would take the lamp to swing back and forth?

Have you ever seen something happen and then wondered how it happened? Did you try to find out how it happened? What steps did you follow to find out?

Puzzled, Galileo went home thinking about how he would find the answers. He spent days finding the materials that he needed. He collected strings, wires, chains, and iron and wooden balls of the same size but of different weights. He also needed an hourglass, his quill pen, ink, and paper. Do you know why the last four things are just as important as the other things?

Now he was ready. He tried out the strings, wires, and chains of different lengths with balls of different weights. At times, he had to try out long lengths of string and wire. To do so, he climbed a tree and hung the weights from the tree.

Galileo Finds the Answers

After many experiments, Galileo found the answers to his questions. Although he did not realize it at the time, Galileo was helping to develop the ways of science that are used by today's scientists. Can you tell how he helped to develop these ways?

Observation helps us to predict what the weather will be.

Observation helps us solve puzzles.

As this point you could read the description of Galileo's observations, and relate the questions he asked (page 6) to your swinging ball.

Have the children guess what results might accompany shortening and lengthening of the supporting chain or rope. These guesses would be hypotheses. Have pupils offer possible explanations for their guesses, but do not label the answers right or wrong. Let later activities in testing hypotheses supply the evidence needed.

Galileo did find answers to his questions. His answers were important in themselves, but even more important in pointing out better ways of finding answers. The text on page 7 asks: "Can you tell how Galileo helped to develop these ways?" The responses should bring to light:

Looking carefully, or observation, is an important part of scientific study.

Comparing things gives us ideas of more and less (quantities).

Instruments are needed to make measurements.

TEACHING SUGGESTIONS
(pp. 8–9)

● **LESSON:** Can we answer Galileo's questions?

Background: In performing this series of experiments, emphasize the need for record keeping. You might wish to avail yourself of the information contained in "How to Record and Use Data in Elementary School Science." This is a brief instructional aid bulletin of the National Science Teachers Association, 1201 16th Street, N.W., Washington, D. C., 20036. Its small cost of 35¢ will be well spent. The booklet explains the relationship of record keeping to the teaching of science as a process of inquiry.

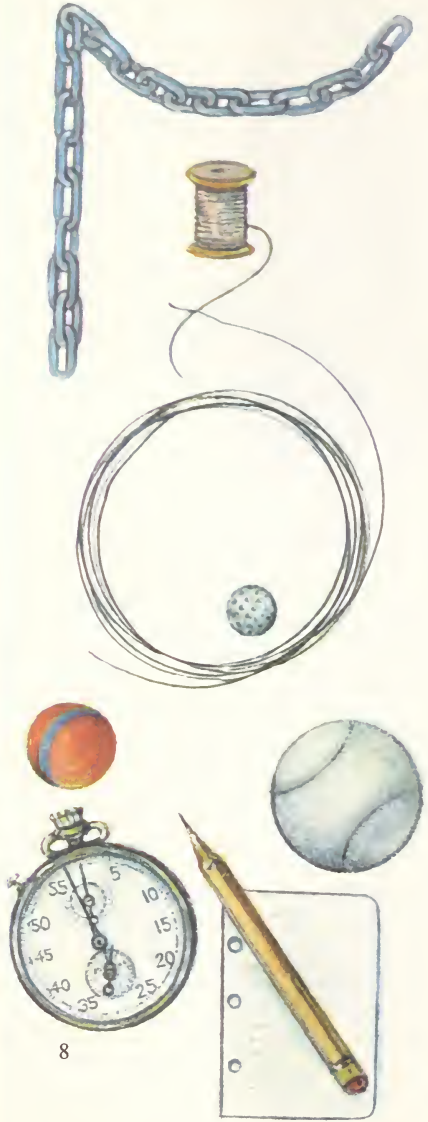
Learnings to Be Developed:

Experiments are done to test ideas or hypotheses.

Record keeping is necessary for experiments to be understood.

Developing the Lesson: Go over page 8 with the children, and explain that the items pictured are merely suggestions. Ask:

- *What kind of swinging objects do we need?* (You should compare large and small, heavy and light objects.)
- *Do we have any objects in the room that we might substitute for those pictured?*



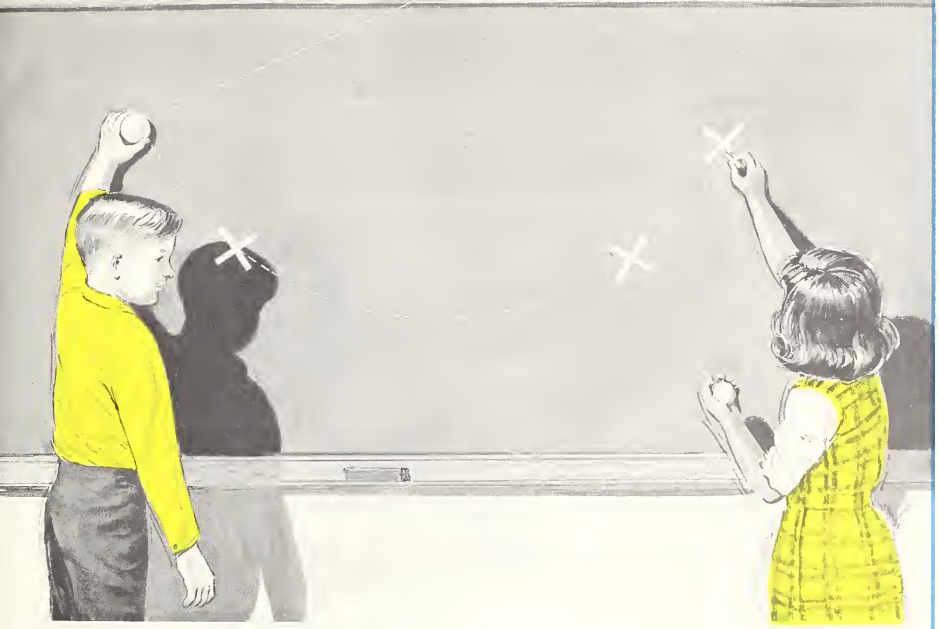
Galileo's experiments proved that Aristotle's ideas about swinging objects were wrong. Anybody can do the same experiments that Galileo did. If he does them carefully, he will find the same answers Galileo found.

You can find out what Galileo found out about swinging objects. Look again at the questions Galileo asked himself and plan experiments to find the answers. You can find the questions on page 6. Here is a list of the materials you will need:

Strings, wires, or chains of different lengths (2 of each).
Balls of different weights, such as rubber balls, golf balls, or baseballs (2 of each).
A watch with a second hand.
Pen or pencil and some paper.

Think about the questions Galileo asked himself. You can find the answers to these questions by doing the following things:

1. Attach strings, wires, or chains of different lengths to balls of different weights.
2. Hang the balls so that they can swing freely—that is, without hitting anything.



The ball makes a curve, or *arc*, as it swings back and forth. How are the children in the picture measuring the distance from one end of the arc to the other end?

Introduce the word arc into the fourth graders' vocabulary.

3. Raise each of the balls, keeping its string taut. Then release the ball. Measure the distance from one end of the arc to the other. Here is a suggestion: Let each ball swing in front of the chalkboard. When the highest position for each swing is reached, mark that point on the chalkboard. See how this is done in the picture.

4. Use a watch with a second hand to time each of ten swings. If you find it difficult to time the swings and count them at the same time, have a classmate time each swing while you count the swings.

What did Galileo measure to find the answers to each of his first three questions? What did he compare?

- *How should we set up and arrange our swinging object?*
- *How should we arrange our information?*

You might suggest a table form for recording the testing of string length changes versus number of swings per minute and weight changes versus number of swings per minute.

- *What effect does lengthening the string have on the time taken for a complete swing of the ball?* (It increases the time.)
- *What effect does increasing the weight of the ball have?* (If the string is not changed, weight differences should have negligible effects on the time of the swing. However, you may encounter friction differences between the surfaces of the chalkboard and the object.)
- *How does the height of the arc on both sides compare in each case?* (If the swing is started from the same height each time, it would be identical.)
- *How does the time taken for the ball to complete a narrow arc, compare with time for a wide arc?* (Swings will be more numerous on a small arc.)

TEACHING SUGGESTIONS
(pp. 10–11)

● **LESSON:** Can we check our answers against the work of others?

Background: Verification of one's own work in science is a bit weak, at best. Scientists are aware of this and look to others to verify their results by performing similar experiments.

On these pages we have a summary in simple form of Galileo's work and conclusions. The conclusions generalize from data and from some statements that are generally true regardless of the objects used. These conclusions fall in the category of answers to how objects behave under certain conditions. The underlying causes are not dealt with here.

Learnings to Be Developed:

We can verify the results of experiments by studying the similar experiments of others.

In an experiment, only one thing should be tested at a time. This thing is called the *experimental factor.*

The unchanging factor is called a *control.*

Checking Your Results with Galileo's

You have now done the same kind of experiments as Galileo. Did you get the same results? Galileo found that:

1. Each swing of a ball took the same time no matter how wide or narrow the arc. When the arc was wide, the ball swung more quickly. When the arc was smaller, the ball moved more slowly. But the time it took to complete a swing was always the same.
2. Each ball swung as far to one side of the center of its swing as to the other. Each ball swung as high to one side as to the other side.
3. The time it took for the ball to swing from one end of its arc to the other depended only on the length of the string.
4. No matter what the weights of the balls, if the strings were the same length, the balls swung from one end of their arcs to the other in the same time.

Did you get the same answers as Galileo did? Aristotle had said that it would take less time for the weight to make a complete swing if the arc were small. But Galileo's experiments proved Aristotle's idea was wrong.

Many hundreds of scientists have done these experiments and proved Galileo to be right. And even though you are not a scientist, you, too, can prove Galileo to be right. Galileo's way — measuring, weighing, timing, testing, and keeping accurate records — has become the way of all scientists.

Reviewing Galileo's Experiment

In doing each part of Galileo's experiment, you compared what happened in one test with what happened in

This scientist is using the ways that all scientists use — the ways that Galileo used.

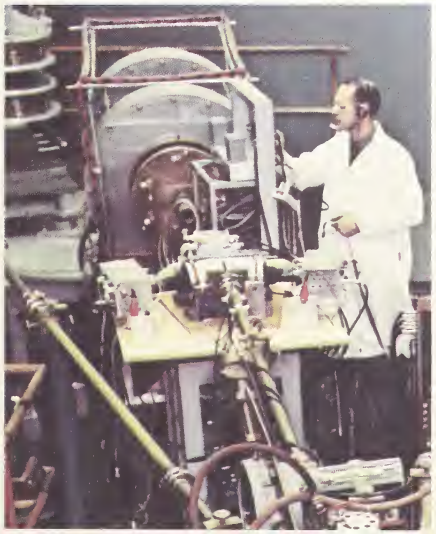
another. The things that you kept the same are called **controls.** Why do you need controls? What controls did you use to answer the questions in Galileo's experiment?

Let's go back to the first part of Galileo's experiment, where he asked, "Does each swing of the lamp last the same amount of time?" He thought that time might change. To check on *time,* he kept the weight of the ball and the length of string the same. Can you tell why he did his experiment this way? What would have happened if he had changed the weight of the ball? In doing an experiment, you test for only *one* thing at a time.

What did you keep the same to find the answer to Galileo's last question, "If a heavier or lighter lamp were used, would that make any difference in the time it would take the lamp to swing back and forth?" What was the one thing you were testing for?

What one thing was different in your experiment? The thing that is different is called the **experimental factor.** There should never be more than one experimental factor in an experiment. Can you tell why?

In the two pictures below, scientists are testing things. Can you tell how they are testing? Look again at the scientist on page 10. What do you think he is doing?



Developing the Lesson: Recall the four key questions asked by Galileo, on page 6, and present a summary of the class's answers to them. For greater impact, you might show them on the chalkboard or on an overhead projector. Study Galileo's answers, one by one, and analyze any differences between the class's findings, and those of Galileo, as presented on page 10.

Impress the idea of control on the pupils by asking what the controls were in each step of the experiments they performed in the last lesson.

Go over the conclusions to the experiment in the last lesson. How do they compare with Galileo's conclusions? Discuss any discrepancies. Determine any possible sources of error. These might include the angle at which the observer stood to make chalk marks, or the difference in speed of reaction of the observer to a change in direction of the swinging ball. Discuss why it is important to find the source of error in an experiment. Discuss the importance of reproducing the results of an experiment.

For an analysis of how eight-to-ten-year olds are likely to think about the pendulum, see Inhelder *and* Piaget, *The Growth of Logical Thinking from Childhood to Adolescence,* pp. 70-73.

TEACHING SUGGESTIONS
(pp. 12–13)

Background: This material will assist you with *Things to Remember.*

1. Ask your pupils how they can be certain that they have all the materials they need to do an experiment. An important way is to make up a written list.

2. Galileo's questions are on page 6.

3. The pendulum (lamp and weights), various supporting pieces (chains and rope), background, and motion were all observed by Galileo.

4. He singled out one variable, or changing thing, at a time, and studied its speed and its distance. In one instance, he kept the string a constant length (control) and varied the weights (experimental factor). In another, the weight was constant while string length was altered.

5. Records by themselves are only notes of observations. They must be studied to see what relationships occur which can help us to solve our problems.

By doing the same kind of experiments that Galileo did, you have used some of the ways of the scientist—measuring, weighing, timing, testing, and keeping accurate records.

You will do many experiments as you find out more about the world in which you live.

Things to Remember

Now let us review some of the important things to keep in mind whenever you do an experiment:

1. Plan your experiment carefully. Make certain that you will have all the materials you need.
2. Be sure you know what questions you want answered. Make a list of the questions. What questions about the swinging lamp did Galileo ask?
3. Know what you must observe to get the answers. What did Galileo observe to get his answers?
4. Be sure you have a way to observe. How did Galileo observe the different swinging balls?
5. Keep an accurate record of everything you observe. Then study your records. Why is it important to study records?

PATHFINDERS IN SCIENCE

Aristotle

(384 B.C.–322 B.C.) Greece

"It is the business of wisdom to discover the causes of visible things."

This thought was written by Aristotle, the Greek scientist and philosopher. It guided him throughout his life.

Aristotle studied a problem by first breaking it down into its smaller parts. Then, having studied the smaller parts, he would try to see how and why the parts fit together.

Before Aristotle, scientific ideas were based on guesses. Aristotle believed that the truth could be found only by observing. He also believed it was important to keep records of what he observed.

There are many ways to observe things. For example, a person might simply watch as a bee sucks nectar from a plant. But Aristotle would do more than just watch what was happening. He would take the bee and the plant home and look inside them to see why and how they were the way they were.

If Aristotle wanted to study the breeding of catfish, he would spend days by the sea watching them. Then he would take one home and cut it open to see what was inside it. His work took many

years, and he collected many, many notes. In fact, he kept records of the habits, breeding, and structure of 455 different animals.

Aristotle was also a thorough researcher. He not only studied the work of those who came before him, he also listened to hunters, fishermen, and farmers who knew much about plants and animals. Every fact was important to Aristotle. He believed and taught that everything that can be observed in each of the sciences is important and must be carefully studied.

When we think of today's scientists at work, we think of microscopes, telescopes, test tubes, and other instruments. Two thousand years ago, when Aristotle tried to learn more about the world in which he lived, there were no such scientific instruments. But even without these instruments he studied almost every known branch of science.

Aristotle's brilliant mind and his ability to teach enabled him to bring together in one place all the knowledge of his time. His own studies and discoveries added much to that knowledge.

Aristotle's ideas about the things he studied were to help men for centuries to come—even to this day. We know now that many of Aristotle's ideas were not correct. But his studies prepared the way for men to find the truth. They served as steppingstones to new discoveries. His lasting contribution to the world was to give scientists knowledge and experience to build upon.

Aristotle was one of the world's greatest thinkers. He studied almost every field of science. His ideas have helped other scientists for over 2,000 years.

Background: Aristotle's father was physician to the king of Macedonia, the grandfather of Alexander the Great.

At the age of 17, Aristotle traveled to Athens to study at the university established by Plato. He became Plato's outstanding student. After Plato's death in 347 B.C., when Aristotle was 37 years old, he traveled widely in the ancient world.

When Aristotle was 42, he was recalled to Macedonia to tutor the future Alexander the Great. He acted in this capacity for six years, until Alexander assumed the throne. Aristotle then returned to Athens and established his own school, known as the Lyceum.

Fascinated by the biological sciences, Aristotle was a very careful and accurate observer. He created a scheme for classifying all living things according to the way their bodies functioned. For example, he classified the dolphin among the mammals because it bore its young alive and fed them with milk, as land mammals do. As may be seen, this is a reasonable scheme of classification and is similar to the system used today.

Aristotle also evolved a system of logic that is still used.

Using What You Have Learned

1. Here are five questions. How would you go about finding the answers to these questions? Do you need to do experiments to answer these questions? Do you need to make comparisons to find the answers to these questions? If so, tell what you are comparing.

   a. Do hamsters like raw vegetables better than cooked vegetables?
   b. Does plant food make potted plants grow better?
   c. Do things weigh less when they are in water or when they are in air?
   d. Does it take less time to bake a potato when it is wrapped in aluminum foil or when it is not?
   e. Which city is farther from your home—New York or San Francisco?

   Would you have to measure anything to get the answers to the questions above? What would you measure? Would you have to time anything? What would you time?

2. Do you always need to do an experiment to find the answer to a question? For example, do you need to do an experiment to find out who is the tallest boy in your school? Can you do an experiment to answer the question, "Is it wrong to steal?"

3. What color is best for the wall of your classroom? Brown? White? Green? Yellow? Which do *you* like best? Which one gives you the most light? You will need a light meter for this experiment. Light meters measure the amount of light. They are used in taking photographs. Perhaps you can borrow one from a friend.

TEACHING SUGGESTIONS
(pp. 14–15)

Background: This material will assist you with *Using What you Have Learned.*

1. The questions a. through e. can all be answered by conducting an investigation. All can be verified by recourse to authority. All are subject to direct observation. Some are subject to experiment.

a. Quantities of raw and cooked vegetables consumed by the hamster are measurable.

b. The term "better" implies growing faster, or growing taller, or growing thicker. And these are subject to measurements of time or size.

c. Direct weight is measurable for comparison.

d. Times can be measured and compared.

e. Distances can be measured and compared.

2. The tallest boy can be found by comparative measurement.

3. Where the question limits itself to likes and dislikes, we cannot find an answer from an experiment. Where the scientific question is asked, "Which color gives us the most light?" then an experiment is possible.

Place papers of different colors inside the box. Use a light meter each time and record the number shown on it. How does the number change when you change papers?

Get a box like the one in the picture and cover the inside with paper of one color. Put an electric lamp in front of the box. Hold the light meter at the other side so that only the light reflected from the colored paper hits it. The more light the paper reflects, the higher the number shown on the meter will be. Now try paper of some other color. Read the meter again. Compare the different colors of paper that you have selected. What did you find out?

4. What color clothing should boys and girls wear to be seen most easily when riding bicycles at night? How would you go about answering this question?

With the use of a light meter placed at a constant distance from the wall (control), you can test the ability of various colored squares (experimental factors) to reflect light. If you use a more precise arrangement, as specified on page 15, the results will be measurable. The specific information you find will depend on the types of pigment in your papers.

4. To answer this question, you could use the experimental set-up described in question 3, above. Instead of using paper sheets, use pieces of colored cloth.

○ ADDITIONAL ACTIVITIES:

Place three or four 500-ml. beakers, or similar containers, side by side on your desk. Fill them to within two inches of the top with the following: one with marbles, one with small irregular stones and pebbles, one with large chunks of stone or concrete, and the last with sand. Ask:

- *Which of these containers has the most space (or air)?*
- *How can we really find out?* (The correct method is to measure the amount of water each container will take.)

TEACHING SUGGESTIONS
(pp. 16–17)

Background: These two pages constitute a review of the concepts and terminology introduced in this unit.

What You Have Learned: This is a summary of the entire unit, with new words in boldface type.

The water displacement experiment on page 15 may be used to review the major concepts of this unit. Ask:

- *What did we compare?* (Available space in each container.)
- *How did we compare?* (Since water occupies space and is visible, we compared the space occupied by water.)
- *Did we use instruments in our experiment?* (A graduated cylinder, a household measuring cup, or whatever was used for measuring the water, was the instrument.)
- *Did we have a nonchanging control?* (Yes. All the containers were of equal size, and the water used in each case was an unvarying substance in its ability to fill space.)
- *What was the experimental factor?* (The substance filling each container: marbles, pebbles, sand, etc.)

WHAT YOU KNOW ABOUT

The Scientist's Way

What You Have Learned

Scientists use **comparisons** to help them get the answers to many of the questions they have about the world around them. But scientists are not the only ones to make comparisons. You, too, use comparisons to learn about things. Sometimes scientists use **instruments** to make more accurate comparisons. You, too, use instruments. You must always measure and compare very carefully and accurately.

Galileo was one of the first scientists to answer his questions by doing **experiments.** In doing his experiments he used comparisons.

When you do an experiment, you should test for only one thing at a time. The things you keep the same are called **controls.** The one thing that is different is called the **experimental factor.** There can never be more than one experimental factor in an experiment at one time.

When you do an experiment, plan it carefully so that you find out what causes the changes you observe. Be sure you know what you want to find out. Make a list of the questions you want answered. Know what you must observe. Keep an accurate record of everything you observe.

Checklist of Science Words

Here are some science words you read about in this unit. Can you tell what you have learned about each one?

comparison	experiment	instruments
controls	experimental factor	

Complete the Sentence

Write the numbers 1 to 5 in your notebook. Next to each number, write the answer that best completes the sentence below.

1. Scientists use special tools called _____?_____ to help them compare things more exactly.
2. The one thing that is different in an experiment is called the _____?_____ _____?_____.
3. The things you keep the same in an experiment are called the _____?_____.
4. Three ways that the scientist uses to compare things are _____?_____, _____?_____, _____?_____.
5. _____?_____ was a scientist who questioned the teachings of Aristotle.

True or False?

In each sentence below, one or more words are underlined. These words make the sentences true or false. Write the numbers from 1 to 5 in your notebook. If the sentence is correct, write "true" next to the number in your notebook. If it is false, write in your notebook the word that will make the sentence true.

1. In an experiment, the one thing that changes is the experimental factor.
2. You cannot find all the answers by experimenting.
3. Aristotle is known as the first of the modern scientists.
4. Observing, timing, and weighing are three of the ways of the scientist.
5. You should never have more than two experimental factors in an experiment.

Checklist of Science Words: Remind the students that there is a *Dictionary of Science Words* on pages 318–325. They should consult this dictionary whenever they are unsure of the precise meaning of a word. Point out that the science dictionary is only concerned with the scientific meanings of words. The same words in a general dictionary might have several different meanings. As an example, use the word *control*. Compare the definition in the text with that in a good standard dictionary.

Complete the Sentence:

1. Instruments
2. Experimental factor
3. Controls
4. Weighing, timing, measuring, testing, or observing
5. Galileo

True or False?

1. True
2. True. The universality of "all" makes this statement true. If you arouse disagreement on this one, discuss examples of unsolved problems which do not allow for experimentation. "Why do we have gravity?" etc.
3. False. Galileo is usually credited with this title.
4. True
5. False. One experimental factor at a time should be studied.

TEACHING SUGGESTIONS
(pp. 18–19)

Background: These pages reinforce the concepts presented in this unit by suggesting activities that extend the pupil's ability to apply the learnings derived from the unit.

Unscramble the Letters:

1. Controls
2. Instrument
3. Comparison
4. Galileo
5. Experimental factor
6. Arc

Can You Tell?

Top right and bottom left are exactly alike.

You Can Read: Here are some additional books for the pupils to enjoy.

Archimedes and His Wonderful Discoveries, by Arthur Jonas (Prentice-Hall, 1963).

Things That Measure, by Philip B. Carona (Prentice-Hall, 1962). The history of measuring devices, with simple home experiments in measurement.

Galileo and Experimental Science, by Rebecca B. Marcus (Watts, 1961). Very readable life story with emphasis on Galileo's experimental work.

YOU CAN LEARN MORE ABOUT

The Scientist's Way

Unscramble the Letters

1. The things you keep the same in an experiment.
2. The special tools of the scientist.
3. Finding out what is different and what is alike about things.
4. One of the first scientists to do experiments.
5. The one thing you change in an experiment.
6. The distance from one end of a swing to the other.

1. NOLTROCS
2. STEMINNRUST
3. SCARPMOINO
4. ALIEGOL
5. MERILATXPEEN CAOFTR
6. RAC

Can You Tell?

Here are four pictures of the same scientist doing the same experiment—but are they really *exactly* the same? Look again. Compare the four pictures and see if you can find the two that are exactly the same.

This activity is a good test of a child's powers of observation.

Do You Know?

Before scientists sent a man into space, they had to do many experiments to make sure it was safe to do so. Read about some of the experiments that scientists and astronauts did in order to send a man into space.

Tell how making comparisons was important in these experiments. You might use these books to help you:

Space Monkey by Olive W. Burt
What Colonel Glenn Did All Day by Robert W. Hill

The astronaut is in a centrifuge that will test his ability to function under conditions in space. As the machine spins, a force presses against the astronaut that produces the effect of artificial gravity. The faster the centrifuge spins, the greater the force.

You Can Read

1. *Great Men of Science* by Arnold Dolin. The stories of many famous scientists.
2. *Tools of the Scientist* by Rhoda Goldstein. Many different scientific instruments are shown.
3. *They Wanted the Real Answers* by Amabel Williams-Ellis. You can find out more about Aristotle.
4. *What Does a Scientist Do?* by Harry Zarchy. An introduction to the world of scientists.
5. *The First Book of Science Experiments* by Rose Wyler. Do your own experiments at home.

Aristotle: Dean of Early Science, by Glanville Downey (Watts, 1962). The life and work of Aristotle simply and clearly set forth for the young reader.

The Tools of Science: From Yardstick to Cyclotron, by Irving Adler (John Day, 1958). This book emphasizes the tools used by the modern physicist in his observations of the matter and behavior of the universe. It is meant for intermediate-grade students.

Through the Magnifying Glass, by Julius Schwartz (McGraw-Hill, 1954). A magnifying glass is one of the most significant tools for children to use in exploring the wonders of the world. Here is a guide for middle-grade children in their own language.

American Women of Science, by Edna Yost (Lippincott, 1955). Of particular interest to girl students.

Films:

Let's Measure: Inches, Feet, Yards. Let's Measure: Ounces, Pounds, Tons. Let's Measure: Pints, Quarts, Gallons. (11 minutes each, Coronet.) They contain a sequence on estimation and its value.

Measurement (11 min., b/w, Coronet). Illustrates how time, temperature, liquid measure, weight, cubic, square, and linear measurement permeate everyday living in our society.

KEY CONCEPTS

Key Concept 1. Events in the natural environment happen in an orderly rather than a haphazard way; man searches for laws to explain this order by observing, hypothesizing, checking his ideas, and rejecting those which do not square with reality.

Key Concept 6. There is a basic tendency toward stability or equilibrium in the universe; thus, energy and matter may be transformed, but the sum total of matter and energy is conserved.

CONCEPTS:

1. Energy is the ability to do work.
2. We get energy from foods and fuels.
3. Energy may be changed from one form to another.
4. It takes a force to start something moving, to change its direction of motion, or to stop it.
5. Work is force acting through a distance.
6. Machines are used to do work.

2

Other concepts appear under "Learnings to Be Developed" in each lesson found in the Teaching Suggestions.

Understanding Energy

Using Energy

Using Simple Machines

What Stops Things That Are Moving?

PROCESSES:

- Observing—Page 22.
- Experimenting—32, 34, 38, 40, 41, 42, 43, 47, 48, 51.
- Comparing—29, 32, 34, 38, 40, 41, 42, 43, 47, 51.
- Inferring—22, 28, 30, 32, 34, 35, 36, 39, 40, 41, 42, 43, 47, 48, 51.
- Measuring—32, 34, 38, 39, 40, 41, 42, 43, 51.
- Classifying—25, 30.
- Selecting (sources from recall)—25, 30, 33, 36, 39, 55.
- Communicating—29, 51, 52, 53, 54.
- Demonstrating—25, 27, 28, 43, 54, 55.
- Explaining—25, 29, 33, 35, 36, 38, 39, 40, 41, 42, 43, 46, 48, 49, 50, 53.
- Hypothesizing or Speculating—49.

TEACHING SUGGESTIONS
(pp. 22–23)

LESSON: What is energy?

Background: As you do work, you use energy, but what happens to the energy between uses? The answer, of course, is that the energy is stored.

You may remember that energy is described as either kinetic or potential. In the kinetic state, energy is produced and motion is taking place. Water falling over a dam is a good example of kinetic, or moving, mechanical energy. It can wear away rocks, and it can move generator wheels. The water behind the dam is an example of potential, or stored, energy. It has the ability to do work.

Learnings to Be Developed:

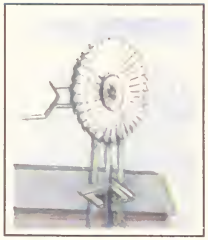
Energy is the ability to do work.

We get energy from foods and fuels.

Developing the Lesson: Begin this unit by having the children study the pictures on pages 20, 22, and 23.

- *What do these pictures have in common?*

Lead pupils to the idea that motion is involved in all of the activities taking place in the pictures. Work is force exerted in the direction of the motion times distance moved.



Pick up your science book. You have just done some **work!** Did you require any **energy** to do this work? Yes, but not much. Energy is the ability to do work. You need much more energy when you go swimming than when you lift a book. But no matter what work you do, you use energy.

Using Energy

Look at the pictures below. See how the falling water turns the wheel. The falling water is doing work. There is energy in the falling water. Look at the next two pictures. Does the wind have energy to do work? Does the wood have energy to do work? What work is each doing?

Light is one form of energy. Electricity is another. Heat is another. And sound is still another. All these forms of energy can do work.

You use energy all the time. It takes energy to move any part of your body. For example, it takes energy to keep your heart beating. It takes

How can you tell if water, wind, and fire have energy to do work? Where does the energy come from? How many different forms of energy can you name?

Look very carefully at this picture. How many forms of energy do you see? How do these different forms of energy do work? Where do you think the energy comes from?

energy just to move your eyes back and forth across this page as you read.

But where do you get your energy from? You get your energy from the food you eat. All food actually has energy stored in it—energy that comes from sunlight. When you read about green plants, you will learn that energy from the sun is in the food you eat. You will also learn that all living things depend directly or indirectly on green plants for their energy.

You eat many foods. In the cells of your body, some of your food is "burned." When this happens, the energy stored in the food is set free. Your cells use this energy to do work. You can pick up things, play games, and do hundreds of things—all because food gives you the energy to do work.

- *Can you describe some work you have done since coming to class today?*

The examples given by the pupils should involve movement: opening windows, putting books away, saluting the flag, turning on lights, etc. If they describe mental work, accept it on the basis that the chemical activity involved in thought is a form of energy, and possibly work. However, you cannot observe the motion involved in thought. Explain to the children that, since they have no evidence of motion, they cannot be certain that work was done.

Now turn to the idea that behind all the work was energy. Discuss the questions in the text. We know the wind has energy because the windmill turns. We know the wood has stored chemical energy, which is released in burning. The rising smoke and flames show motion of particles.

Background: The forms of energy shown on page 22 are falling water, wind, and chemical (heat).

- *How many forms of energy do you see in the picture on page 23?* (Electrical, heat, chemical, mechanical, water, sound, and light are all illustrated. The explanation of how they do work should in all cases involve motion.)

TEACHING SUGGESTIONS
(p. 24)

● **LESSON:** Where does the energy to do work come from?

Background: The precise concept of a machine will be clarified later in the unit, with the work beginning on page 31. For this lesson, use the term *machine* in the general sense of a device that performs some function. The emphasis is on the machine as a user of energy. The ultimate source of energy in our planetary system is the sun.

Learnings to Be Developed: Most sources of energy on earth can be traced to the sun.

Developing the Lesson: Make a list on the chalkboard of all the work done by machines for the children since they awoke this morning.

Electrical: alarm clock, radio, stove, toaster, school clock, bell.
Heat: toaster, stove, furnace.
Mechanical: wheels of auto or bus, door knob, sewing machine, lock on briefcase.
Chemical: breakfast, fuel for auto.

Background: The answers to the captions on page 24 are: Electrical energy runs the press. The press does mechanical work. Chemical energy of gas is used in the stove. Its source is the sun.

Machines Use Energy to Do Work

Suppose you wanted to travel across the United States. Of course, you could walk about 3,000 miles across the country, but it would take too much energy for you to do that. It would be much easier to use the energy of machines. Machines make use of different kinds of energy. Machines can make use of mechanical energy, electrical energy, and heat energy.

We use electrical energy to run big machines, like printing presses and elevators, and to run small machines, like vacuum cleaners and washers. We use heat energy to cook our meals. Scientists use nuclear energy to run submarines. Do you know what else they use nuclear energy for?

Many kinds of energy are used daily to get things done—to do work. Make a list of all the work you did today in which you used energy that did not come from your own muscles.

Where Does Energy Come From?

Anything that can burn has energy stored within it. Coal, oil, and gas have energy stored within them. When they are heated, the energy is released.

What forms of energy are being used to run the printing press? What type of work is being done by the printing press?

What form of energy is being used to cook the food on this gas range? Where does this form of energy come from?

can be neither created nor destroyed, but only transformed from one form to another. For example, in an engine, the stored chemical energy in gasoline is changed to the kinetic energies of heat and motion.

Most of the energy in our world comes from the sun. Without the sun there would be no food, coal, oil, or gas—our principal sources of energy.

Energy Can Change Its Form

One example of how energy can change its form is found in the automobile engine. When someone starts an automobile engine, gasoline begins to burn inside the engine. The burning gasoline creates heat. This heat, which is a form of energy, makes certain parts of the engine move. These moving parts of the engine make other parts of the car move. Scientists say that when an object moves, that object is using **mechanical energy**. Do you see how the energy inside an automobile engine is changed from heat energy to mechanical energy? You will learn later how other forms of energy can be changed.

This is an atomic submarine. From where does this submarine get its energy? From where does this form of energy come?

Energy Has Many Forms

Rub your hands together. You are now using the energy of motion, or mechanical energy. Keep rubbing. Are your hands getting warmer? You are changing mechanical energy into heat energy.

Here is another example of energy being changed from one form to another. Pump air into a bicycle tire. After you push the plunger down and pull it up a few times, feel the pump. Is it warm? Explain what happened.

Stored Energy

You have been reading about **energy in action**. There is another kind of energy. It is called **stored energy**. Stretch a rubber band. The stretched rubber band has stored energy within it. Let one end go. It snaps back and hits your finger. The stored energy becomes energy in action.

(See pages 26–27 for the second law of thermodynamics.)

TEACHING SUGGESTIONS
(p. 25)

● **LESSON:** Can energy change from one form to another?

Background: Changes in the form of energy occur with no loss in total energy involved. An understanding of these conversions is based on an understanding of the law of conservation of energy, and the second law of thermodynamics.

Learnings to Be Developed: Energy can be converted or changed from one form to another.

Developing the Lesson: Take a massive object like a ball of clay. Hold it up before the class. Ask:

- *Does this contain energy?* (Yes, stored energy.)

Drop the clay on a paper tent.

- *How did the stored energy do work when it fell?* (It flattened the tent.)

Follow this by illustrating other changes: Light a match. Chemical energy changes to light and heat. Have children rub their hands together. Mechanical energy changes to heat. Turn on a light switch. Electrical energy changes to light.

TEACHING SUGGESTIONS
(pp. 26–27)

Background: Joule was born the son of a wealthy brewer, and inherited the brewery upon his father's death. His chief interest, however, was in scientific research. In particular, he set out to discover what the exact relationship was between work energy and heat energy.

One of his crucial experiments on the relationship between work and heat is illustrated in the diagram. The container is filled with water. There are a number of paddles fastened securely to the sides of the container, while another set of paddles is fastened securely to a movable rod that extends into the container. As these paddles turn past each other, they encounter the resistance of the water.

The amount of work done is defined as the weight of an object times the distance the object moves in a horizontal direction.

PATHFINDERS IN SCIENCE

James Prescott Joule

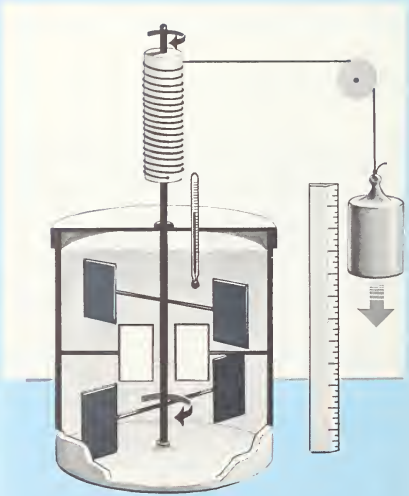
(1818–1889) England

We know that heat is a form of energy. But we didn't *always* know this. Someone had to find out.

At the end of the eighteenth century, scientists thought that heat was something taken in by an object when the object's temperature rose. When the object's temperature fell, the heat supposedly escaped into the atmosphere. Since the weight of an object is not changed by heating, scientists reasoned that heat was weightless. This explanation worked very well for materials that were heated over a flame, but it didn't really explain the heat given off by friction.

In the 1840's an amateur scientist, James Prescott Joule, set up an experiment in which a small paddle wheel kept

James Joule used the materials below to find out if a certain amount of mechanical energy always produces the same amount of heat.



turning in a certain amount of water. He was able to measure the amount of heat given off by the friction of the paddle wheel turning in the water. He also measured the amount of mechanical energy caused by the friction. Joule discovered that a certain amount of mechanical energy always produces the same amount of heat.

Next, he answered the question, "What does heat have to do with friction?" Joule found that a certain **amount of motion** (or **friction**) always turns into the **same amount of heat.** One kind of energy is simply changed into another. Every bit of mechanical energy given off becomes heat energy. This experiment showed that heat is another form of energy and *not* a "substance."

Joule's work led to one of the basic laws of science. His experiments showed that when one form of energy is changed into another, no new energy is created and no old energy is destroyed. One kind of energy is simply changed into another kind. In 1847, another scientist, Heinrich von Helmholtz, put these findings into words as the *Law of the Conservation of Energy.* This law says that energy can be changed from one form to another but cannot be created or destroyed.

Stored Energy to Energy in Action

A blown-up balloon has energy stored within it. Stick the balloon with a pin and the stored energy becomes energy in action.

Bob did not know about stored energy. Knowing about stored energy might have helped him. Before going away on vacation, Bob placed some blankets in a box on a very high shelf. Finding it hard to keep the cover closed on the box, he placed a large book on top of the box. When he came home from his vacation, he needed the blankets. He stretched up on his tiptoes and pulled the box down. But he forgot about the book. Down it came, hitting Bob on the forehead.

...much with. Potential energy involves a high degree of orderliness in the molecules of the constituting material, while kinetic energy is the energy of random or disorderly

In the diagram, work is done by the weight as it falls toward the ground. As the weight falls, it pulls the string, which causes the cylindrical rod to rotate, which causes the paddles to turn. As the paddles turn, the energy of the falling weight is expended in overcoming the resistance of the water. The energy is thus transferred to the water and results in an increase in the temperature of the water.

Knowing exactly the amount of work accomplished and noting the rise in water temperature that resulted, Joule was able to calculate the exact relationship between work done and the amount of heat produced. It turned out that 41,800,000 ergs of work produced a quantity of heat called one *calorie.* This relationship is known as the *mechanical equivalent of heat.* In Joule's honor, the quantity of work in 10,000,000 ergs is called a *joule,* so that 4.18 joules of work are equal to 1 calorie of heat.

Bob found out that the book had energy stored in it. And this energy was released when the book fell. The book did work—although Bob was not very happy about the work it did.

Lift a weight. The weight now has stored energy. How did it get there? Drop the weight. What happens to the stored energy? The stored energy is changed into mechanical energy—the energy of motion. Energy can do useful work, but it can also cause accidents if you are not careful.

Setting Things in Motion

A moving object has energy. It can do work. But what starts an object moving? Bicycles, roller skates, wagons, toy cars, sleds, and swings do not start to move by themselves. Things stay where they are unless something starts them moving.

Could your book move by itself? What could happen to make it move? What things could you do to move it?

How would you move your chair? Would you move the teacher's desk in the same way? Would you move a heavy desk in the same way if the floor were covered with a thick rug?

It always takes something called **force** to set anything in motion. Force is the push or pull on an object. When you walk, run, skate, ride a bicycle, hammer nails, throw a ball, or turn the pages of this book, you are using force. Even if you push against a wall and it does not move, you are still using force. You just are not using enough force to move the wall. It takes more force to

How is the boy below using force? Is he doing any work? How can you tell?

TEACHING SUGGESTIONS
(pp. 28–29)

● **LESSON:** How does a scientist describe changes in motion?

Background: Isaac Newton first described the laws of motion. We are concerned here with his first law which, for simplicity's sake, can be restated: If no outside force is exerted on an object, the object will remain at rest or will continue to move in a straight line at constant speed.

For our purposes, force is energy that changes motion or rest. You will not find such a definition in any dictionary, but it will prove useful for explaining changes in motion in this and subsequent lessons.

Learnings to Be Developed:

A force is needed to start something moving.

A force is needed to change directions of motion.

A force is needed to stop motion.

Developing the Lesson: Perform a live demonstration. Place a baseball on the chalk tray and discuss its potential, or stored, energy.

Give the ball a push with a force sufficient to propel it along the chalk tray. Ask:

move something heavy than to move something light.

Scientists say that work is done only when a force actually *moves* an object. When you push as hard as you can against a wall, are you doing any work? You might think so, but a scientist would say that you are not. Since the wall you push against does not move, you are not doing any work.

Why doesn't the wall move? The force you use is not great enough to move the wall.

Energy, force, and *work* are words that you have used for a long time. But now you are using them in new ways—the ways scientists use them. You have found that these words all have something to do with each other. Before reading on, can you tell how they are related to each other? Which of the three must always come first?

Here is an example of how energy, force, and work are related. You have *energy* in your muscles. When you use your muscles to throw or "push" a baseball, you are producing a *force*. Since the baseball moves through the air, you have done *work*.

Can you now explain how energy, force, and work are related in each of these groups of words:

1. Gasoline, snow plow, snow
2. Boy, rock, windowpane
3. Horse, corn and oats and hay, wagon
4. You, pencil, notes
5. Cat, milk, tree

Would you say that in each case the work done was *useful* work? Does work have to be *useful* to be work?

How is this boy using force? Is he doing any work? How can you be sure of your answer?

- *What caused the motion?* (The push given by your hand.)
- *What stopped the motion?* (Whatever you placed at the end of the chalk tray.)
- *When we started the ball moving, and again when we stopped it, what action took place?* (A force, or push, began motion. A force applied at the end stopped motion.)

Discuss the questions on page 29.

1. Gasoline's chemical energy is changed to heat energy to provide mechanical energy to do the work of pushing, or forcing, the snow away.

2. The boy converts chemical energy to have his muscles force the stone to move and do the work of breaking the window.

3. The horse eats foods which give him stored energy which in turn is used to pull or force the wagon to do work.

4. Your muscular energy forces the pencil to move and do the work of writing.

5. The cat takes in food. Energy in the food is converted to muscular energy and forces his body to do work in getting up the tree.

TEACHING SUGGESTIONS
(p. 30)

Background: The following material will provide you with information for the *Using What You Have Learned* section.

Force (i.e., kinetic energy) is being expended in moving the automobiles, to turn the concrete mixer mounted on the truck, to hoist the concrete to the top of the building under construction, by the people walking down the street, and by the workmen.

The only work being done in the picture (according to the technical definition of work: work = application of a force over a distance, as long as the distance is measured in the direction of the force) is the raising of the bucket of cement to the top of the building. The workmen are doing work only when they are raising objects.

Chemical energy in gasoline in the automobiles is converted into mechanical energy in the automobile engines to accelerate the automobiles down the street, to rotate the concrete mixer, and (unseen) to raise the bucket of concrete to the top of the building. The human beings are also expending chemical energy which is converted into mechanical energy by their muscles.

Using What You Have Learned

Here is a picture of a busy street. There are many kinds of machines and many kinds of energy being used. Look carefully and list in your notebook the different kinds of machines and the kinds of energy you find.

Can you tell where force is being used in the picture below? Can you tell how many different kinds of work are being done? Can you tell how energy, force, and work are related in the activities taking place in the picture?

How will the boy lift the rock? Is he using a machine? How would you lift it? How are energy, force, and work related in the activity?

Some pupils may know the word "lever." A stick or iron bar used in this way is a lever. A lever is a simple machine.

Using Simple Machines

Suppose you want to move a heavy rock. You can move it the way the rock in the picture is being moved. You are using a machine to help you—an iron bar. You may not think of an iron bar as a machine, but it is one. The iron bar is really a simple machine called a **lever.**

Not all levers are iron bars, but levers generally work in the same way as the iron bar that you see in the picture. When a carpenter uses his hammer to pull a nail, the hammer is really a lever. When you use a shovel to dig, the shovel is a lever. When you use a shoehorn to put on your shoes, the shoehorn is a lever.

You can lift a heavy pile of books with a lever right in your classroom. A broom handle or stick can be a lever.

TEACHING SUGGESTIONS
(p. 31)

LESSON: What are some simple machines?

Background: A machine is a device that simplifies the work of man by saving time or shortening distance. For example, the pulley is a simple machine. Simple machines are ones that are reduced to a single function. Some classifications reduce them to two: the lever and the inclined plane. This is based on the fact that a pulley and the wheel and axle are in reality levers with the fulcrum at the center. The wedge and screw are considered inclined planes.

Learnings to Be Developed:

Machines are used to do work.

Work is a force acting through a distance.

Developing the Lesson: Start dramatically by asking if a girl in the class will volunteer to lift you off the floor. Place a large board over some bricks like a seesaw, but with one end of the board much longer than the other. Stand on the short end. Now have the child stand on the long end. Despite the differences in weight, she will be able to raise you off the floor.

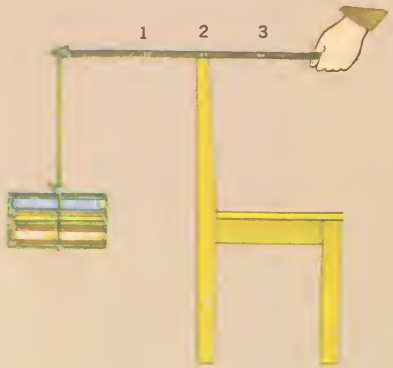
How Does a Lever Help to Move Things?

What You Will Need

broom handle or stick
long, heavy string
pencil or other marker
pile of books
chair

How You Can Find Out

1. Tie the books together with the string.
2. Then tie the string to the end of the broom handle or to the stick.
3. Make three marks on the stick, as you see in the picture.
4. Now put the stick over the back of the chair.
5. Try lifting the books three separate times with the stick resting at a different mark each time.



Questions to Think About

1. At which mark does it take the least force to lift the books?
2. At which mark does it take the greatest force to lift the books?
3. What does this tell you about one way to lift a heavy weight?

TEACHING SUGGESTIONS
(pp. 32–33)

● **LESSON:** How does a lever help to move things?

Learnings to Be Developed: A lever is a machine that makes it easier to raise or lift things.

Developing the Lesson:

- *What are two important things we must have in an experiment?* (A control and an experimental factor.)
- *What was the control factor in the experiment?* (The constant weight of the books.)
- *What was the experimental factor?* (The changing distances on the stick or broom handle.)

Background: The following material will assist you with the answers to *Questions You Can Think About.*

1. At mark 1. Here, the distance from the pivot (fulcrum) is greatest for your force, and least for the books' downward force (gravity).

2. Greatest force is needed at mark 3.

3. The place where you apply your force should be as far away from the pivot (fulcrum) as pos-

How Do Wheels Help Things Move?

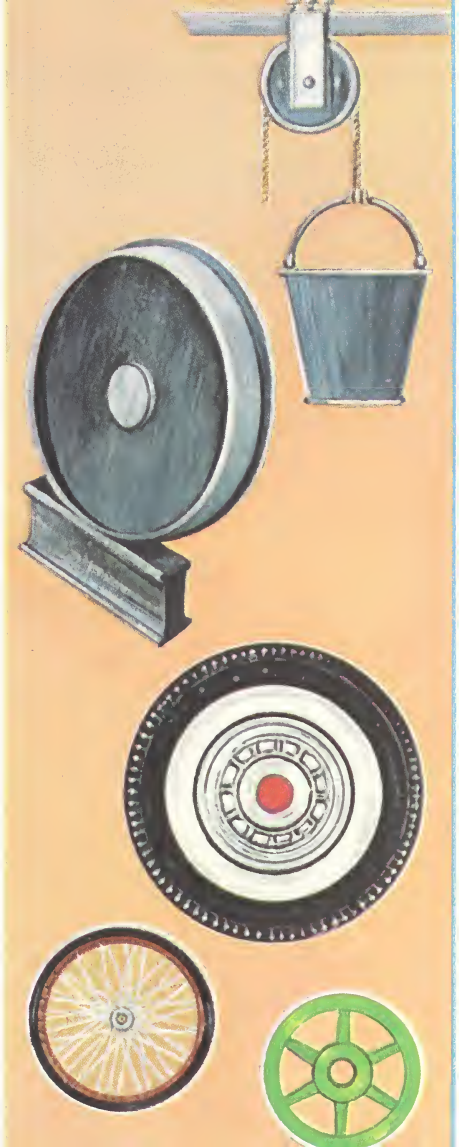
Many things are too heavy for people to move. But sometimes these things can be moved with the help of wheels. The pictures show some ways of using wheels to help move things. How are the wheels of each thing moved? The **pulley** in the picture is a simple machine. A pulley is used for lifting objects.

Sometimes wheels are moved by the force supplied by other wheels that are turning. This happens when you use an eggbeater, or when the little wheels turn inside a watch or a clock.

Wheels are moved by the force supplied by other wheels when you ride on your bicycle. The muscles of your legs supply the force that makes the sprocket wheels turn. When two sprocket wheels like those on a bicycle are joined by a chain, what happens when one of them is turned?

The experiment that begins on the next page will help you find out about sprocket wheels on a bicycle and how they work together. Do you know how a sprocket wheel got its name?

How are these different kinds of wheels used to move things? What kinds of wheels are they?



sible, and the thing you are lifting should be as near the pivot as possible.

Follow-Up: Assemble the following devices: a nutcracker, a pair of scissors, a pair of pliers, a soda-can opener, a small crowbar, a toothpick, a knife, a fork, a paddle. Exhibit them to the class and discuss the functions of each. Have members of the class demonstrate the use of each. Ask:

- *Why are all these instruments classified as machines?* (They use energy to do work.)
- *What else do they have in common?* (They all are levers. They all function by applying a force to move an object some distance from the point at which the force is applied.)

If there is a seesaw (a lever) on the playground, have the children balance themselves perfectly. If there is a weight difference, you will notice that they know they must move nearer to, or further away from, the center (fulcrum) to achieve balance. Point out to them that they have discovered, empirically, the formula for balancing the lever: the product of the force applied on each side of the lever times the distance from the forces to the fulcrum must be equal.

What Happens When a Bicycle's Sprocket Wheel Is Turned?

What You Will Need

bicycle watch with a second hand

How You Can Find Out

Part I

1. Turn a bicycle upside down and turn the pedals slowly with your hands.
2. What happens to the two sprocket wheels?
3. Does one move faster than the other?
4. What does the chain do?
5. What would happen if the chain broke?

Part II

1. Stop turning the pedals, but do not put on the brake.
2. Do the sprocket wheels stop turning right away?
3. Turn the pedals faster. What happens?
4. Stop turning the pedals. Does the back wheel stop as quickly now as it did when you turned the pedals slowly?

Part III

1. Turn the pedals slowly for 15 turns.
2. Measure the time it takes the wheel to stop. (Two or three timekeepers would be better than one.)
3. Now turn the pedals fast for 15 turns.
4. Measure the time it takes the wheels to stop.
5. What does this tell you about stopping a bicycle when you are riding it?
6. Count the sprockets on the front sprocket wheel. Then count the sprockets on the rear sprocket wheel. What does this tell you about how the two sprocket wheels are related?

TEACHING SUGGESTIONS
(pp. 34–35)

● **LESSON:** How do wheels act as machines?

Background: The wheels illustrated on page 33 fall into two categories. They are used either to cut down on friction or to provide some advantage in speed or direction.

Learnings to Be Developed:

Combinations of wheels can be used to increase speed.

More force is needed to stop a faster moving wheel than a slower moving one.

Developing the Lesson: Discussion of the text on page 33 should precede the experiment.

Background: This material will help you with answers to the questions on pages 34 and 35.

Part I
2. They both turn.
3. Yes. The rear sprocket wheel.
4. The chain follows the sprocket wheels and transmits the motion from its source to the rear wheel.
5. Force would not be transmitted to rear wheel.

Part II
2. No.
3. The sprocket wheels continue rotating for a longer period than in No. 2.

This picture is a closeup view of the sprocket wheels of the bicycle.

Questions to Think About

1. Watch the two sprocket wheels on the bicycle when the wheel is turning. Can you tell why one is made smaller than the other?
2. Suppose the two sprocket wheels were changed so that the small one was near the pedals. Would the wheel go faster or slower if you turned the pedals?
3. The front wheel of the bicycle does not turn when the pedals are turned. What makes it turn when you ride?
4. Why is the rear tire of a bicycle likely to wear out before the front tire? Can you think of two or three reasons?
5. When you ride a bicycle, how are energy, force, and work related?

may find that a wheel which increases speed loses power, while a powerful transmission of energy results in a loss of speed.

4. No.

Part III

5. The faster you ride, the harder it is to stop, and the longer it will take.

6. A 20″ bicycle usually has 36 sprockets on the front and 20 on the rear. Larger bicycles have 20 on the rear and up to 40 on the front pedal. The speed is increased two to one.

Background: The following will provide information for *Questions to Think About.*

1. The smaller rear sprocket wheel moves faster than the larger front sprocket wheel.

2. The rear wheel would go slower.

3. The rear wheel is attached to the frame, and motion forward is transmitted to all parts. The front wheel reduces friction.

4. The total force of beginning motion is on the front wheel, as is the friction of fast stops.

5. Muscular energy does work in moving the pedals. The pedals transmit this force to the rear wheel by means of the chain and sprocket wheels.

TEACHING SUGGESTIONS
(pp. 36–37)

● **LESSON:** How is the energy of gases used to do work?

Background: The kinetic molecular theory is the basis for modern explanations of the behavior of gas: Gas is matter. Matter is composed of tiny particles. These particles are in constant motion and vibration. As energy (heat) is supplied to the molecules, their activity increases. Where many particles are acting, as in a container of gas, increased activity causes large forces to be produced.

Gases expand at a tremendous rate when heat is applied. A steam boiler produces expanding water in a gas form. At great pressure, the gas acts somewhat like a rushing wind. If it is directed against mechanical pieces, such as pistons, then the heat energy is converted to mechanical energy.

In fuels such as gasoline, the stored chemical energy is converted to heat energy in burning. The heat produces an instantaneous gas expansion, which in turn produces a force which manifests itself in the mechanical work done by a piston.

Learnings to Be Developed: Expanding gas produces a force which can be used to do work.

How Do Steam and Other Gases Make Things Move?

Some wheels are moved by the force that our muscles produce. The wheels on your bicycle and on a wagon are moved this way. But many wheels are moved by another force—the force of a gas. In Tom Peterson's class, the teacher and students tried to see how this happens.

Tom put a cork in an empty can like the one in the picture. His teacher heated the can for a few minutes. What happened to the cork? As the air inside the can got hotter, the air took up more space. Since there was not enough room for the air in the can, the air pushed harder against the cork and the sides of the can. The air pushed so hard that it blew the cork out of the can. What would happen if you pumped air *out* of the corked can?

Do you know what sometimes happens to the lid of a pot when the water boils inside the pot? The lid bounces up and down. Do you know why? When you boil water, the water turns to steam. Since steam takes up more room than water, it pushes upward on the lid. The steam pushes with so much force that it raises the lid.

The force produced by large amounts of steam is used to turn the wheels of big machines. Can you think of other ways in which steam is used to move things?

This is what happens when a corked can is heated a few minutes. Why does the cork pop? What safety measures should you take when doing this experiment?

What force makes this boy slide down the hill?

How do you know the boy will hit the ground?

When gasoline burns, it changes to a gas very quickly. The stored-up energy is then released as heated gas. It pushes with great force against anything in its way. The force that is made by releasing this energy is used to turn the wheels of cars. It is also used to turn the propellers of airplanes. Can you tell about other things?

How Gravity Makes Things Move

There is still another force that makes things move. Hold a pencil in front of you. What happens if you let go? The force that makes the pencil fall is called **gravity**. It is the gravity of the earth that makes things fall to the ground unless there is something to hold them up.

What does the force of gravity have to do with each of these pictures?

Developing the Lesson: Perform the demonstration on page 36. Be sure the can is free from any volatile fluids (mimeo fluid, kerosene, etc.). If an open flame is used, have a fire extinguisher handy. Don't place the cork on too tightly, and keep children a safe distance from the demonstration area. The cork in the illustration pops because the force of the increased activity of the gas molecules forces the cork from the can.

After the demonstration, direct your discussion toward finding the main difference between this and your earlier demonstration with the test tube. (Heat energy versus chemical energy.)

Follow-Up: Have children collect pictures for a display of engines that do work by using the force of expanding gases.

ADDITIONAL ACTIVITIES:

Some children may have toy models of cylinders, cutaway sections of automobile motors and rockets. Have them bring them to class and explain the transformation of energy that takes place in these working models.

EXPERIMENT

How Can You Measure the Force of Gravity?

What You Will Need

old inner tube
chalk or other marker
stones, sand, bits of paper, or anything you wish to weigh
toy pail
water
heavy string

How You Can Find Out

1. Cut a long strip of rubber from an old inner tube. It should be about three feet long.
2. Tie a toy pail to one end with heavy string.
3. Tie a loop of string to the other end and hang it from the wall or from a coat hook.
4. Use a piece of chalk to make a mark on the wall next to the bottom of the rubber strip.
5. Now fill the pail with water.
6. Make another mark on the wall to show how far the rubber stretched.
7. Try this with different things, such as stones, sand, bits of scrap paper, cotton, and sawdust.
8. Mark how far each one makes the rubber stretch.

Questions to Think About

1. Which one was pulled toward the earth with the greatest force?
2. Which one was pulled toward the earth with the smallest force?
3. How have you measured the force of gravity?

If there were no force of gravity, things would not weigh anything. When we say that a girl weighs 70 pounds, we mean that the earth's gravity is pulling her towards the earth with a force of 70 pounds. A 5-pound bag of sugar is pulled toward the earth with a force of 5 pounds. A pound of candy is pulled toward the earth with a force of 1 pound.

TEACHING SUGGESTIONS
(pp. 38–39)

● **LESSON:** How can you measure the force of gravity?

Background: Isaac Newton realized that, as Galileo had pointed out, a body moves in a straight line unless acted upon by another force. This meant that the moon would not circle the earth unless there were an attractive force which kept it from moving away in a straight line; somehow the moon must be attracted to earth. From this, Newton developed the law of gravitation. This law states that all objects in the universe attract all other objects with a force called gravitation.

Learnings to Be Developed:

Gravity is one of the most important forces on the the earth.

One measure of the force of gravity is the weight of an object.

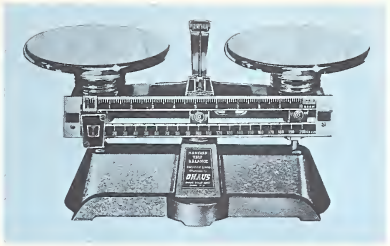
Developing the Lesson: Your children probably already have some awareness of gravity and can easily answer the picture questions on page 37.

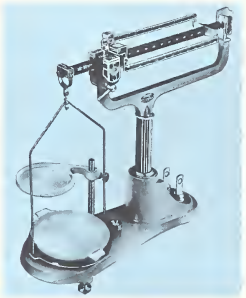
Discuss the experiment on page 38 in terms of the things being compared. These are the amounts of downward pull on an equal amount of different substances.

Here are some interesting questions about gravity for you to think about.

1. What force of gravity is pulling your body toward the earth?
2. Sometimes birds high in the air seem to float without moving their wings. Why doesn't the force of gravity pull these birds to the earth?
3. If it were not for the force of gravity, what would happen at a ball game when a batter hit a high fly?

On page 38 you learned one of the ways to measure the force of gravity. Scientists have instruments that can measure gravity more accurately. Do you know the names of any of these instruments? How are the two scales in the pictures different from each other?





When Things Fall from High Places

Which would be more likely to hurt you—a fall from the bottom step of a ladder or a fall from the top step? Which would hit the ground harder—an apple falling from the top of a tree or an apple falling from your hand?

You can show what happens to things falling from high places by measuring how deep they sink into mud. The experiment on the next page will help you.

These scientists are using an instrument called a *gravimeter* to measure the force of gravity.

Background: The following material will provide you with answers to the *Questions to Think About* section.

1. The water will probably prove to be the right answer here, since it is one of the densest common substances.

2. This will vary with the substances used. Whichever is the lightest will fall with the smallest force.

3. The measurement was a gross comparison of weights. You did not assign any units such as pounds, etc. If you feel it desirable, the experiment could be repeated using a spring scale instead of the tubing.

Background: The following material will provide you with the answers to the three questions on page 39.

1. The child's weight.

2. The force of gravity is not as great as the upward force generated by the wings of the bird on the particles of air. Level flight would indicate a balance of forces upward and downward.

3. It would soar into space.

EXPERIMENT

How Does Height Affect the Force of a Falling Object?

What You Will Need

shallow pan	ruler or tape	mud
marble	measure	ladder

How You Can Find Out

1. Fill a pan with mud.
2. Make the mud just soft enough so that a marble will leave a hole in it.
3. Drop a marble into the mud from a place three feet high. Measure how deep a hole it leaves.
4. Now drop the same marble from a place six feet high. Measure how deep the hole is.

Questions to Think About

1. Are both holes the same size?
2. Which is deeper? What does this show?

This experiment shows you that the farther something falls, the harder it will hit. It hits with more force because it is going faster. The farther it falls, the faster it goes.

Gravity is a force. Like other forces, it speeds things up as long as it acts. The longer you pump on a swing, the faster it will go. Pumping supplies the force. Even if the pumps

TEACHING SUGGESTIONS
(p. 40)

● **LESSON:** How does height affect the force of a falling object?

Background: As an apple is attracted to the earth by gravity, it falls at the rate of 16 feet in its first second. The following second it falls 32 more feet. We say that the apple accelerates 32 feet per second, every second.

Learnings to Be Developed: Falling objects have greater force from greater heights.

Developing the Lesson: If possible, have each child try the experiment. You might wish to substitute a nonhardening clay for the mud.

Background: The following material will help you with the answers to the *Questions to Think About* section.

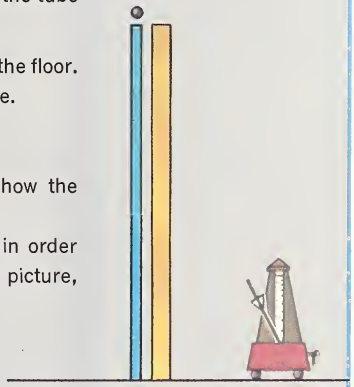
1. One hole should be deeper than the other.

2. The hole made by the six-foot drop should be deeper. More impact force was generated in the longer drop under longer influence of gravity. *Note:* Since speed was not the experimental factor here, do not accept it as an observed explanation. The next experiment will deal with acceleration.

How Much Do Things Speed Up As They Fall?

What You Will Need

long, narrow tube of polyvinyl (3 feet, if possible)
marble
heavy-weight oil to fill the tube
metronome
strip of cardboard as long as the tube



How You Can Find Out

1. Fill the tube with oil, and hang it with its base touching the floor.
2. Stand the cardboard upright along the side of the tube.
3. Start the metronome.
4. At the first tick, drop the marble in the oil.
5. With each tick, make a mark on the cardboard to show the position of the marble.
6. Cut the cardboard at each mark, and paste the pieces in order on heavier cardboard. This will give you a graph, or picture, of how the marble speeded up. Label your graph.

Questions to Think About

1. How far did the marble fall between the first tick and the second tick?
2. How far did the marble fall during each time period after that?
3. During which time period did it fall the farthest?

are the same size, you will swing faster, so long as you keep on pumping.

The force of gravity is acting all the time on earthbound objects. For example, when an apple falls from a branch, gravity pulls the apple to the ground. Its constant pull speeds up the apple as it falls. The farther the apple has to fall, the more it speeds up. You can see this happening.

TEACHING SUGGESTIONS (p. 41)

LESSON: Does any change in speed occur as an object falls?

Learnings to Be Developed: The longer an object falls, the greater its speed.

Developing the Lesson: Follow the procedure of the experiment as outlined.

Background: The following material will provide you with the answers to the *Questions to Think About* section.

1. A ruler can give you your answers from the graph.

2. Again, accurate records can be checked against the ruler.

3. The last time unit should produce the greatest distance. Indicate that speed is the result of distance ÷ time. If exact average speed is needed for each time interval, simply take the bar representing the distance, measure it and divide by the time unit. The important conclusion to derive from this work is that, in a freely falling object, speed increases as time increases.

EXPERIMENT

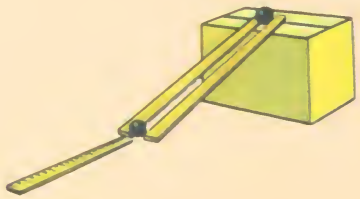
Do Things Hit Harder If They Fall Faster?

What You Will Need

marbles two yardsticks ruler or tape measure

How You Can Find Out

1. Roll a marble down a slope.
2. Use two yardsticks to keep the marble rolling straight down the slope.
3. Let it hit another marble at the bottom of the slope. Measure how far that bottom marble moved.
4. Make the slope steeper. Roll a second marble down the slope. Measure how far the bottom marble moved.



Questions to Think About

1. What happens to the bottom marble when the slope is steeper? Is it moved farther?
2. Try several different slopes. What happens each time?

What do the experiments so far tell you about what happens when you bump into a fence while running for a ball? Would you hit against the fence as hard if you were walking?

Why is there danger in going too fast on bicycles, roller skates, wagons, sleds, or other moving things? Why is there danger to yourself and to others if you run in the school halls?

TEACHING SUGGESTIONS
(pp. 42–43)

● **LESSON:** Do things hit harder if they fall faster?

Background: Among Galileo's greatest achievements were his studies of the properties of motion: speed, velocity, and acceleration. Speed is a measure of distance over time, velocity is a measure of speed plus direction, and acceleration is a measure of the gain in speed and distance of a moving body.

In the experiment in this lesson, you are measuring the kinetic energy of the acceleration of gravity. A body falls at a constant acceleration of 32 feet per second for every second it falls, after falling 16 feet during the first second. Obviously, we cannot measure this in the classroom in a meaningful way; instead we measure the increased energy a body acquires, the faster it falls.

Learnings to Be Developed: More force is produced by a fast-moving object than by a slow-moving one.

Developing the Lesson: Recall the experiment on page 40. The results of that experiment showed that force increased with height. Ask the children how this experiment is different from the experiment on page 40. (Here, we are con-

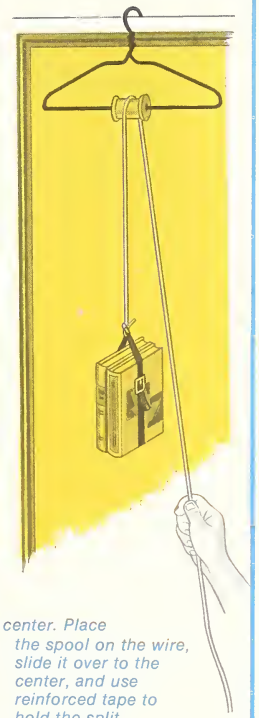
Using What You Have Learned

1. With a pulley you can lift things *up* by pulling *down*. If you don't have a pulley, use an empty thread spool and a coat hanger wire to make a pulley. Hang your pulley in the center of an open door. Run a string over the pulley so that the ends of the string nearly touch the floor. The picture shows how the pulley should look. You can now lift up different things by pulling down on the string.

2. With a string, tie a book to one end of a long, heavy rubber band. Tie the other end of the rubber band to a coat hook or something else that sticks out from the wall. When the book stops bouncing up and down, measure how far it hangs from the coat hook.

   Now lift the book until it no longer stretches the rubber band at all. Then let go. Notice how far it stretches the rubber band on the first bounce.

   Why does the book stretch the rubber band farther than it did when it was just hanging?



Use a strong wire coat hanger. Use wire cutters to cut it at a point off center. Place the spool on the wire, slide it over to the center, and use reinforced tape to hold the split ends together.

3. You can show how rollers make things easier to move. Get a box about the size of a chalk box. Put stones or other heavy things inside it. Put the box on the floor and fasten a rubber band to one end of it. Hold a ruler beside the band and pull on the band until the box just begins to move.

   How long was the band stretched when the box started to move?

   Now put two round pencils under the box and pull on the rubber band. How long was the band stretched this time when the box started to move?

cerned with speed, rather than height.)

Background: The following material will provide you with the answers to the *Questions to Think About* section.

1. It moves farther when the slope is steeper.

2. The faster the falling marble, the farther the target marble will be propelled.

Background: The following material will provide you with information for the *Using What You Have Learned* section.

1. The advantage of a pulley lies in the fact that it is easier to pull something down than to haul it up.

2. If children have understood the purpose of the three experiments on gravity forces, they should see that the moving energy of the book is greater than its stationary energy when the pull of gravity balances the pull of the elastic.

3. This will serve to introduce the next section of work. The wheels (pencils) made friction negligible and less force was needed for movement of the box.

TEACHING SUGGESTIONS
(pp. 44–45)

● **LESSON:** What stops things that are moving?

Background: Sir Isaac Newton's first law of motion, mentioned earlier, states that an object will continue in motion until some force outside of itself changes that motion. Children find it reasonable to expect a rolling marble to cease motion if the force of a hand or other object stops it. The idea that friction can also stop motion is a bit more difficult to grasp.

Several explanations of friction have been proposed. The most common belief of physicists is that friction is caused by irregularities on the surfaces of the contacting bodies. When surfaces move over one another, they tend to interlock and offer resistance to motion. Smoothing or polishing the surfaces, then, should result in less friction, and such is the case. However, there is a limit to how much friction may be reduced by polishing. If the surface between polished surfaces is too smooth, the friction between them actually increases. Explanations of this increase are made in terms of electrical attraction. Perhaps the total explanation is a combination of both.

What Stops Things That Are Moving?

You know that nothing will move unless some force makes it move. In the same way, nothing will stop unless some force makes it stop. Someone on roller skates will keep moving for a while after he has been pushed. A bicycle wheel will keep moving for some time after you have stopped turning the pedals.

It is not very easy to stop roller skating when you are moving very fast. Can you tell why?

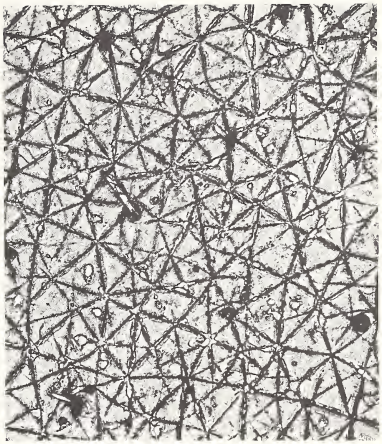
Just as you must apply force to make things move, you must apply force to make things stop. You remember that to make an object move, you had to apply force in the direction you wanted the object to move. But to make an object stop, you apply force in the direction opposite to its motion. The size of force you apply must be larger than the force that is acting on the object.

A car will coast for a time by itself, but after a time it will slow down and stop. In the same way, a boy on roller skates cannot coast forever. The car and the boy on roller skates stop because there is a force opposing their motion, even though you cannot see it. This force is called **friction** (FRIK-shun). Friction is created whenever two things rub against each other. For example, there is friction when your bicycle tires roll over the roadway. There is friction when ice skates glide over the ice. There is friction when a boat moves through the water. Even when you simply rub your hand lightly over the top of your school desk, friction is created.

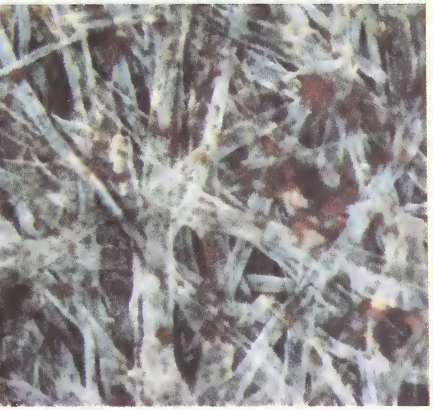
How Does Friction Stop Things?

Nothing is ever perfectly smooth, even though some things look smooth. Every surface has little bumps and hollows on it. If you look through a magnifying glass at something that is smooth, such as your skin or a page from a book, you will see that it is not as smooth as you thought it was.

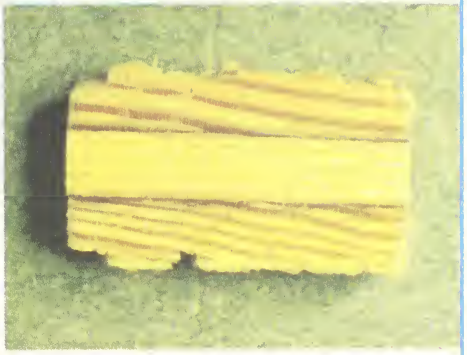
These little bumps and hollows act as a force which can slow down and stop a moving thing. The little bumps and hollows on one object rub and catch against the bumps and hollows of



Skin



Paper



Wood

Look at all three pictures. Can you tell which is skin, which is paper, and which is wood? How are their surfaces different from one another?

In this section, the work centers around the first explanation of friction.

Learnings to Be Developed:

Motion is slowed or stopped by friction.

Friction is caused by uneven surfaces in contact with each other.

Developing the Lesson: Try variations of the inclined plane experiment on page 42. Set it up so that the marble moving down the slope can roll until it stops of its own accord. Let the marble roll onto several different kinds of material: smooth waxed floor, rough door mat, wrinkled newspaper, etc.

Have pupils measure the distances that the marble rolls from the foot of the slope, and record the differences of several trials on each kind of material.

Next, change the angle of incline of the slope, making it sharply steeper for one series and markedly less steep for a second series.

Record data of all the trials, in chart or graph form to make the results more readily understandable and to help develop children's skill in graphic representation. Have pupils explain the differences in data, using the proper terms for different kinds of energy.

TEACHING SUGGESTIONS
(pp. 46–47)

LESSON: Why is friction needed?

Background: Friction is a force. Forces are needed to begin motion or to change it. The force of friction is needed to change motion or to stop it. Treat friction in your discussions as a *negative force*, or a force that opposes motion.

Learnings to Be Developed: Friction is necessary as a force to control and stop motion.

Developing the Lesson: With a magnifying glass, examine the surfaces of a waxed floor, a piece of glass, and a newspaper. Notice the roughness of the newspaper compared to the others. Discuss these surfaces in terms of the experiment in the previous lesson.

- *Is there a relation between the length of the run of the marble and the texture of the material on which it ran?*
- *What can you conclude about the data of that experiment in terms of the surfaces of the various materials?* (Roughness is directly related to friction, which alters the length of the run.)

Ice skates glide smoothly over the ice. Can you tell why they are able to do so?

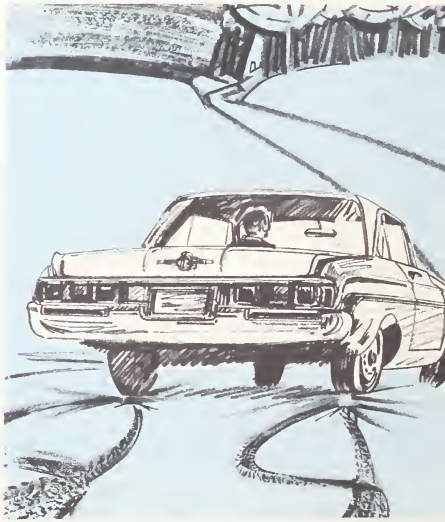
another object. This slows down the motion of the moving object.

If the two objects have many bumps and hollows in them, there is a great deal of friction. When two very smooth objects move against each other, there is not much friction. That is why ice skates slide easily on ice. For the same reason, a car or a bicycle skids on ice and keeps on moving longer than it would move on a dry road.

When we want to make objects move more quickly, we can use what we know about friction. Can you tell why cars go faster on smooth highways than on rough roads? Can you explain why railroad trains run on steel tracks? Can you tell why children's playground slides are so smooth?

You can find out what happens when there is very little friction. The next experiment will help you find out.

What safety measures must be taken when it becomes necessary to drive on icy roads?



What Happens When There Is Very Little Friction?

What You Will Need

small square of wood (about ½" thick)
glue
sandpaper
balloon
spool
wax

How You Can Find Out

1. Make a small hole through the center of a small square of wood about half an inch thick.
2. Glue a small spool over the hole.
3. Sand and wax the bottom of the wood.
4. Blow up a balloon and stretch it over the spool. Keep your finger over the hole in the bottom of the wood so that no air comes out.
5. Take your finger away as you put the wood on a smooth surface such as a clean window pane.

Questions to Think About

1. Give the wood a push. What happens?
2. Can you explain what happened?

- *What kind of energy is friction?* (Heat, which is produced by the movement of surfaces against each other. Remind pupils about rubbing their hands together earlier in the unit on energy.)

Proceed now to the experiment as outlined on page 47. If you wish, you might substitute a "frictionless" puck, available at small cost from most science supply houses.

Background: The following material provides answers to the *Questions to Think About* section.

1. It seems that the square of wood could continue in a straight line until air from the balloon is exhausted. Very little friction is encountered.

2. The puck and the glass or wood surface are not in contact. The cushion of flowing air keeps the puck off the table surface. The result is a lessening of mechanical rubbing of two solid objects. Fluid substances, such as air, produce less friction than solid substances.

Follow-Up: Have children develop a list of conditions where little or no friction is needed.

List all the conditions that pupils encounter during the day, where steps are taken to reduce friction.

TEACHING SUGGESTIONS
(pp. 48–49)

● **LESSON:** How can our knowledge of friction help us to travel safely?

Background: Science should lead man to intelligent action. In this unit we are studying science as a servant which makes life easier and safer. The rules the children learn in this section should be made directly applicable to their daily behavior.

Learnings to Be Developed: An understanding of the nature of friction can help us prevent accidents.

Developing the Lesson: Proceed immediately with the experiment as outlined on page 48. The answers to the questions here should be evident as the children go through the steps of the experiment.

Follow-Up: Have the children list all the places in school where friction is used to control motion. Suggested places would include typewriter rollers, mimeograph machines, rubber tires on cleaning equipment, friction of fingers in turning pages, etc.

Study the construction of the windows in the classroom. What provisions were made to help them slide easily up and down?

Scientists have shown that once a thing is moving, it will keep on moving until it is stopped by something. Why does the piece of wood in the experiment finally stop?

Have you ever heard of a "runaway" car on a railroad track? How far will it go before it stops? What stops it?

Do you know how the brakes on an automobile work? Is the automobile stopped by friction?

We can use what we know about friction to travel more safely. The next experiment will show you how.

EXPERIMENT

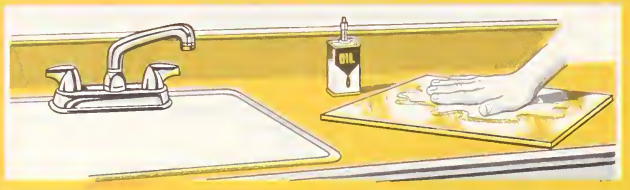
How Will Knowing About Friction Help You Travel More Safely?

What You Will Need

water piece of glass oil

How You Can Find Out

1. Rub your hand over a piece of glass.
2. Pour a little water on the glass.
3. Rub your hand over the glass again. Does your hand move more easily?
4. Dry the glass and pour a little oil on it.
5. Rub your hand over the glass again. What happens?



Questions to Think About

1. What does this tell about riding over wet or oily roads?
2. What do you think would happen if you tried to stop a bicycle or a car suddenly on a wet or oily road?

Look at a bicycle or car tire. Notice the grooves in the rubber. Can you tell why the tires are made this way?

Tires will skid on icy, wet, or oily roads. Old, smooth tires will skid more easily than new ones. Can you tell how tire chains help to keep a car from skidding?

Highway workers spread sand on icy roads because sand makes the roads rough. This roughness makes more friction, and cars can stop more easily.

Can you think of some ways to prevent accidents while riding a bicycle, while driving a car, or while walking on a slippery road?

What does each of these pictures have to do with what you now know about friction?

What provisions were made to keep them at one spot?

One method of reducing friction between two moving surfaces is by using bearings. There are many types of bearings which children might be able to bring to class. A good example of how effective ball bearings are can be shown by placing a coffee can weighted with sand on a table and attempting to rotate it. Slight difficulty is encountered. Now place six or seven marbles in a circle under the can and rotation becomes much more simple.

ADDITIONAL ACTIVITIES:

Construct a diorama of the history of tools (machines). Read the history of the great buildings such as the pyramids of Egypt, the temples of Athens, the temple of Solomon. Show how some of these primitive tools and machines might have been used in such construction.

Visit a construction site and study the simple and complex machines used today.

Visit the high school shop and have the instructor display and explain the machines there.

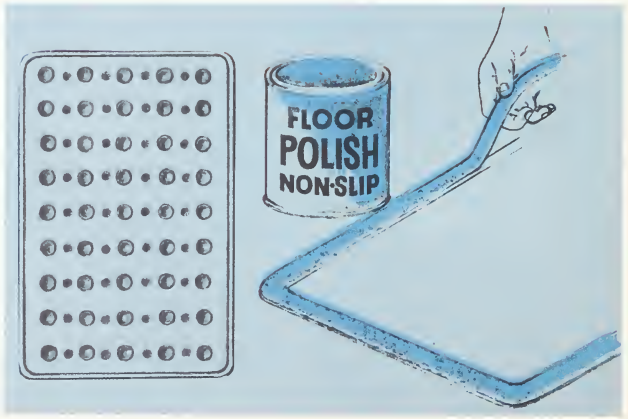
Using What You Have Learned

1. Which of these four would move in the same direction for the longest time, after the first push? Why?

   A sled with steel runners on ice.
   A sled with steel runners on fresh snow.
   A sled with wooden runners on ice.
   A sled with wooden runners on fresh snow.

2. Many accidents in the home are caused by sliding or slipping. These can be prevented if you think about the way friction keeps things from sliding. How could you use friction to keep the following accidents from happening?

   Slipping in the shower or bathtub.
   Falling on slippery floors.
   Falling when rugs slip.



TEACHING SUGGESTIONS
(pp. 50–51)

Background: The following material will provide you with information for the *Using What You Have Learned* section.

1. Since all the characteristics of the runners and the sled are not given, it might be well to raise some questions before trying to answer the main point.

- *Do we know the width of the runners?* (Thin ones might cut deeply into snow but ride high on ice.)
- *Do we know the weight of the sled?* (In snow, the weightier sled would run deep, while the light one would be high on ice.)
- *To answer this question by an experiment, what would we have to have as a control?* (A sled that is the same weight and a runner that is uniform in width and length in each of the four trials. The conclusive answer would be the sled with the wooden runners on fresh snow.)

2. A bath mat with suction cups is commercially available, or adhesive friction strips can be placed on the floor.

3. Have a bicycle "rodeo" in your schoolyard to show safe bicycle riding. At one school's bicycle rodeo, three boys tried to find out how fast they could stop their bicycles. The boys found out that the faster they went, the more time it took them to stop. Try this at your rodeo. Measure how long it takes to stop when you are going at 5 miles per hour, at 10 miles per hour, and at 15 miles per hour.

4. Using what you have learned, make up a set of rules for safe bicycle riding. You may also want to have a bicycle "checkup." Everyone who owns a bicycle might check to see if all the parts are working properly. Be sure to check brakes, front lights and taillights, and horn.

Using rubber-soled shoes or rough, composition soles will eliminate this hazard. Covering the floor with a slip-proof mat is also possible. Industrial firms treat slippery floors with a coating of nonskid paint or wax.

Rugs should be either permanently anchored to the floor or else provided with a slip-proof underlayer of rubber or composition.

3. For your more advanced pupils, you might have an introduction to the meaning of *momentum*. Momentum is the mass (weight) of a body multiplied by its velocity (speed in a straight line).

4. Follow up this activity by calling on your local police department to provide a speaker on the topic of bicycle safety. Arrange for a complete bicycle safety check of all the bicycles in the class. This is sometimes done by local police departments, Kiwanis or Lions Clubs, or recreation departments. Certificates of inspection are usually supplied by the above groups as an incentive to proper bicycle behavior and operation.

TEACHING SUGGESTIONS
(pp. 52–53)

Background: These two pages constitute a review of the concepts and terminology introduced in this unit.

What You Have Learned: This is a summary of the entire unit, with new words in boldface type.

Checklist of Science Words: Remind the students that there is a *Dictionary of Science Words* on pages 318–325. They should consult this dictionary whenever they are unsure of the precise meaning of a word.

WHAT YOU KNOW ABOUT

Understanding Energy

What You Have Learned

Energy is the ability to do **work.** There are many kinds of energy. **Light, electricity, sound,** and **heat** are four kinds of energy. All energy can be traced back to the sun.

Energy can change its form. For example, light energy can be changed into heat energy. **Stored energy** can become **energy in action.**

Producing a **force** takes energy. When forces move an object, work is done. If you cannot move an object by yourself, you can use simple machines to help you. **Pulleys** and **levers** are two kinds of such simple machines.

Gravity is one of the most important forces that start things moving. If there were no such force as gravity, nothing would stay down.

Friction makes things stop. When two things move against one another, there is friction. Knowing about friction can help us prevent many car and bicycle accidents. It can also help us prevent many accidents in the home.

Checklist of Science Words

Here are some science words you read about in this unit. Can you tell what you have learned about each one?

energy	friction	mechanical energy
energy in action	gravity	stored energy
force	lever	

Complete the Sentence

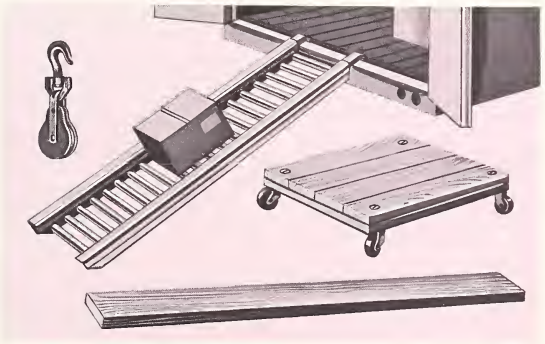
Write the numbers 1 to 5 in your notebook. Next to each number, write the answer that best completes each sentence below.

1. Almost all energy comes from the _____?_____.
2. The energy of motion is called _____?_____ energy.
3. The names of two simple machines that help us to move things are _____?_____ and _____?_____.
4. The force that makes things fall is _____?_____.
5. A force that slows things down is _____?_____.

What Would You Do?

Here are four pictures of simple machines. Tell which machine you would use to help you do each of the things listed below.

1. Lift a heavy rock.
2. Raise a flag on a flagpole.
3. Move a box filled with heavy books across the room.
4. Move something heavy from the street to the sidewalk.



Complete the Sentence:

1. Sun
2. Mechanical
3. Lever, inclined plane, pulley, screw, wedge, or wheel and axle
4. Gravity
5. Friction

What Would You Do?

1. The heavy plank or lever
2. The pulley
3. The dolly
4. The ramp or inclined plane

TEACHING SUGGESTIONS
(pp. 54–55)

Background: These pages reinforce the concepts presented in the unit by suggesting activities that extend the pupil's ability to apply the learnings derived from the unit.

Unscramble the Letters:

1. Energy
2. Mechanical energy
3. Energy in action
4. Stored energy
5. Force
6. Lever
7. Gravity
8. Friction
9. Electricity
10. Sound

YOU CAN LEARN MORE ABOUT

Understanding Energy

Unscramble the Letters

1. The ability to do work.
2. The energy of motion.
3. The opposite of hidden energy.
4. Energy that is hidden.
5. The push or pull on an object.
6. A simple machine that helps you to lift things.
7. The force that makes things fall to the earth.
8. A force that slows things down.
9. A form of energy.
10. Another form of energy.

1. GYREEN
2. INACHEMLAC NGEYRE
3. NGYREE NI TACINO
4. REDTSO REYGEN
5. CEROF
6. RELEV
7. TIVGRAY
8. NOCIRFTI
9. YECLTITERIC
10. DSUNO

You Can Make an Exhibit

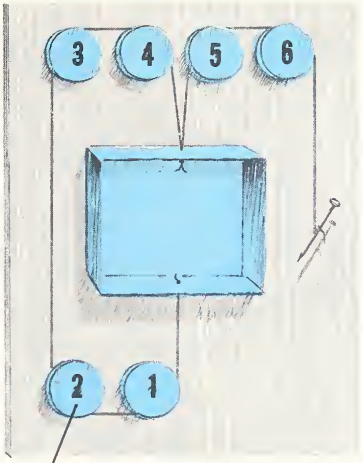
There are many things that help you use energy safely. You can collect them and make an exhibit. You may want to invite other classes to see your exhibit. Ask them if they can tell how the things in your exhibit help people to use energy safely.

You might collect such things as potholders, which protect you from heat energy, and insulated wires, which protect you from electrical energy.

You Can Build an Elevator

You will need a 1′ x 2′ piece of wood, 6 empty spools, 7 nails, a small cardboard box, and 2 pieces of string.

Attach the spools to the board as shown in the picture. Make holes at the top and at the bottom of the box. Put one piece of string through the hole at the bottom and knot it inside the box. Now, wind this piece of string around the spools as you see in the picture. Attach the second string to the first, and pass it over spools #5 and #6. Tie a nail to the end of the string. Turn spool #2 to operate your elevator.



You Can Read

1. *Your World in Motion* by George Barrow. The story of energy in its many forms.
2. *Thank You, Mr. Sun* by Hy Ruchlis. Shows how energy comes from the sun.
3. *Everyday Machines and How They Work* by Herman Schneider. Many different machines are shown.
4. *Simple Machines and How They Work* by Elizabeth H. Sharp. How simple machines are used.
5. *Now Try This* by Herman Schneider. Tells about many simple machines and how they work.

You Can Read: Here is some additional reading for the teacher.

Intelligent Man's Guide to Science, Vol. 1, Physical Sciences, by Isaac Asimov (Basic Books, Inc., 1960). This is a wonderful guide for the teacher in all the areas of physical science.

The Origins of Modern Science, by Herbert Butterfield (Collier, 1962). Essay #1 on "The Historic Importance of a Theory of Impetus" and Essay #8 on "The History of the Modern Theory of Gravitation" are excellent reading for teachers.

Additional books for pupils include the following:

Push and Pull: The Study of Energy, by Paul Blackwood (McGraw-Hill, 1959).

Orbit: A Picture Story of Force and Motion, by Hy Ruchlis (Harper and Brothers, 1958).

Friction All Around (Whittlesey, 1960); *Gravity All Around* (Whittlesey, 1963); *Machines and How We Use Them* (Whittlesey), by Tillie S. Pine and Joseph Levine.

Man and Power, by L. S. DeCamp (Golden Press, 1961).

Machines at Work, by Mary Elting (Garden City Press, 1962).

KEY CONCEPTS

Key Concept 1. Events in the natural environment happen in an orderly rather than a haphazard way; man searches for laws to explain this order by observing, hypothesizing, checking his ideas, and rejecting those which do not square with reality.

Key Concept 6. There is a basic tendency toward stability or equilibrium in the universe; thus, energy and matter may be transformed, but the sum total of matter and energy is conserved.

Key Concept 8. There is a relationship between structure and function; the structure of parts of living organisms determines the function of those parts.

3

Other concepts appear under "Learnings to Be Developed" in each lesson found in the Teaching Suggestions.

Living Things—Green Plants

Green Plants—The World's Food Makers

Green Plants—How They Survive

Green Plants—How to Grow Them

CONCEPTS:

1. All living things are dependent upon green plants for food.
2. Green plants carry on photosynthesis (energy is needed).
3. The structure of green plants makes it possible for them to carry on food-making processes.
4. Green plants are adapted to different environments.
5. Man protects some plants from unfavorable temperatures and from their natural enemies.
6. Man provides the materials needed by plants.

PROCESSES:

- Observing—Pages 66, 67, 68, 70, 71, 72, 92.
- Experimenting—66, 67, 68, 70, 71, 72, 92.
- Comparing—66, 67, 68, 70, 71, 72, 92.
- Inferring—66, 67, 68, 70, 71, 72, 84, 90, 92.
- Classifying—74.
- Selecting (sources from recall)—58, 62, 63, 65, 66, 72, 73, 75, 76, 78, 81, 89, 98.
- Communicating—59, 75, 98.
- Demonstrating—59, 67, 89, 95, 98.
- Explaining—61, 74, 75, 77, 78, 91, 98.

(pp. 58–59)

LESSON: Where do we get our energy?

Background: The endless cycle of food production, consumption, utilization for energy, deterioration, and eventual re-use of raw materials has its beginning in the green plant.

This unit lends itself to several experiments which may be conducted either by pupils or as demonstrations by the teacher, to illustrate different aspects of photosynthesis. Some teachers may wish to introduce the topic by telling about Van Helmont's famous experiment from which he concluded that all plant growth came from water. You may then wish to discuss the experiments of Lavoisier and Priestley, who showed that carbon dioxide from the air was taken in, and oxygen given off, by plants.

Learnings to Be Developed: All living things are dependent on green plants for their energy.

Developing the Lesson: You might begin this unit by asking pupils to raise their hands.

Where did the energy come from to do this?

You have learned that you get your energy from the food you eat. In Unit 2 you learned that food has energy stored in it—energy that comes from sunlight. Energy is the ability to do work. The energy your body uses to do work comes from sunlight by way of green plants.

Green Plants—The World's Food Makers

Scientists call green plants the world's food makers. Let's see why. Make a list of the foods you had last night for dinner, and this morning for breakfast. How many of these foods come from green plants?

Our fruits and vegetables come from green plants. Foods like lettuce and spinach are the **leaves** of green plants. Still others, like cauliflower and broccoli, are the flowers of green plants. Corn and beans are the seeds of green plants. Foods like carrots and radishes are the **roots** of green plants. Asparagus is the **stem** of a green plant. Can you think of other foods that come from different parts of green plants?

Look over your list of foods again. Are there any foods on your list that do not come from green plants? Did you have meat for dinner? Meat certainly does not come from a green plant. But think carefully. What do cattle, sheep, hogs, and poultry eat? You are right if you said grain or grass

or seeds. All the foods for these animals are, or come from, green plants. Most of us enjoy eating steaks, hamburgers, chops, and chicken. These meats come from cattle, sheep, hogs, and poultry. So you see, not all our food comes *directly* to us from the plants themselves.

You can show step by step how all your food can be traced back to green plants. For example, did you eat eggs for breakfast? Eggs come from chickens, which get their food from corn. Corn is a seed of a green plant. You, in turn, eat the eggs laid by chickens. Now can you show step by step how some of the food you eat can be traced to green plants? You might start by tracing milk back to green plants.

What part of a green plant is each of these vegetables? How can you find out about them?

When a pupil suggests that it comes from food, ask where the food comes from. As each pupil names a food, ask him to trace the food back to its original source. Write the information on the blackboard:

FOOD	ANIMAL	PLANT
Butter	Cow	Grass
Cereal		Wheat
Beef	Cow	Grass
Fish	Smaller fish	Green algae
Eggs	Chicken	Corn

Pupils should soon see that we depend upon green plants ultimately for all of our energy.

ADDITIONAL ACTIVITIES:

Have students inspect all the packaged breakfast cereals to determine the basic plant ingredient of each.

Investigate where in the world people eat seaweed—a simple green plant.

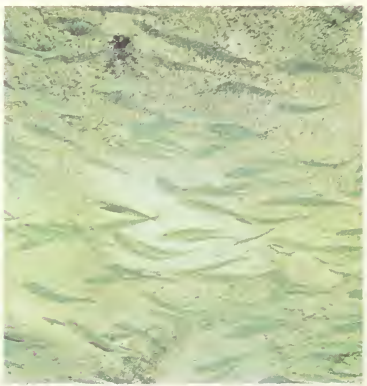
Why do these peoples eat seaweed? (It is abundant and there is very little other food available.)

Animal Life Depends on Green Plants

Large animals may feed on smaller animals, which, in turn, feed on plant life. For example, the polar bear eats seals for food. Seals eat fish. These fish feed on smaller animals. These smaller animals feed on green plants that live in the ocean.

Do you know why all animal life depends on green plant life? Animals cannot make their own food. Green plants can. Animals must have ready-made food, either from plants or from

The polar bear depends on green plants for its food. But it eats seals, and seals eat small fish. Explain, then, the first sentence.



TEACHING SUGGESTIONS
(pp. 60–61)

● **LESSON:** Are green plants necessary to animal life?

Background: All living things are dependent for their food on the sun's energy, which is trapped by green plants. This fact raises the question of how many people the earth can comfortably support. The answer ultimately depends on the amount of the sun's energy that can be trapped by photosynthesis.

Possibly 80 to 90 per cent of photosynthesis occurs in marine and fresh-water environments. This may be a clue to a new source of food. Perhaps we can farm the seas, or cultivate in tanks, algae fit for food. At present, such a method is not economically feasible, but studies along these lines are being carried forward against the time when it may be necessary to get more food from the sea.

Some day we may understand photosynthesis so well that we will be able to control and improve its efficiency within the plant, or even duplicate the process efficiently outside the living cell. It is no longer true that scientists cannot make sugar without chlorophyll. For some time, sugars have been synthesized by

smaller animals that eat plants. That is why you and all the animals on earth depend on green plants.

Right now, in laboratories in many parts of the world, scientists are doing experiments to find out just how green plants make their own food. They already know a great deal, and you will read about what they know. But there are still many questions to be answered. When scientists find the answers, people may no longer have to depend on green plants for food. Why will this be a great discovery?

Many scientists in many parts of the world spend a great deal of time studying green plants. When they find out how carbon dioxide and water combine in a green plant to make food, they will have made a major scientific discovery.

chemists in the laboratory. However, the efficiency of the leaf is so much greater than that of the scientist that test-tube synthesis is presently impractical.

Learnings to Be Developed: Animal and human life depend on green plants for food.

Developing the Lesson: Have the children draw up lists of the foods of common household pets and farm animals. Trace all these foods to their source in plant life. Analyze other things in human existence which depend on plant life and its products.

- *How did the discovery of seeds enable early man to change his food habits?* (It enabled him to change from a hunter to a farmer.)
- *What clothing materials are plants products?*
- *What building materials are derived from plants?* (Construction lumber; tar products, such as asphalt; waterproofing resins; roofing; plastics; veneers; varnish.)
- *Do you know of any home products which are derived from plants?* (Furniture polish; turpentine and paint bases; paper products, such as toweling, tissue, and picnic plates; linoleum; disinfectants, etc.)

TEACHING SUGGESTIONS
(pp. 62–63)

LESSON: Does the green in plants have any function?

Background: Inside the green leaf, carbon dioxide from the air is combined with water from the soil in a chemical process which utilizes light energy to produce sugar and oxygen. Only green plants, plants containing chlorophyll, can do this.

Until recently, the nature of the process of photosynthesis was almost completely shrouded in mystery. In recent years, however, through a series of experiments, research scientists have done much to uncover many intermediate steps in this process. For details see references at end of chapter (BSCS yellow and blue versions).

The chemical reaction for this process may be written:

$$\underset{\text{carbon dioxide}}{6CO_2} + \underset{\text{water}}{6H_2O} \xrightarrow[\text{chlorophyll}]{\text{sunlight}} \underset{\text{glucose}}{C_6H_{12}O_6} + \underset{\text{oxygen}}{6O_2}$$

Sugar (glucose) is stored by the plant in a compact form as starch.

Learnings to Be Developed:

Green plants carry on photosynthesis.

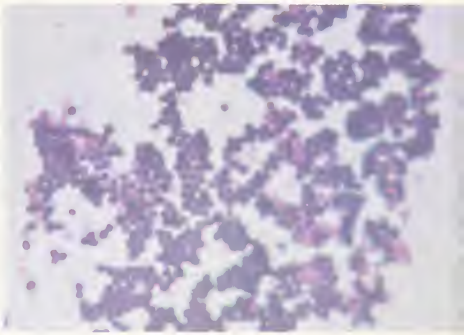
The "Green" in Green Plants

There are some plants that are not green. Mushrooms, bacteria, and a few flowering plants like beechdrops and Indian pipe are examples of plants that are not green. Do you know any others? Where do these plants get their food?

What makes some plants green? These plants, or parts of them, are green because they contain the green chemical **chlorophyll** (KLOR-uh-fil). Chlorophyll gives these plants their green color. Chlorophyll enables the green plant to make food.

None of these plants has the green chemical chlorophyll. Like animals, these plants must depend on green plants for their food. How do they get their food from green plants?

Mushrooms



Bacteria

Beechdrops

Indian pipe

Energy—from the Sun to You

Did you know that a plant *works* when it makes food? You know that it takes energy to do work. It takes energy to make food. Where does the green plant get energy?

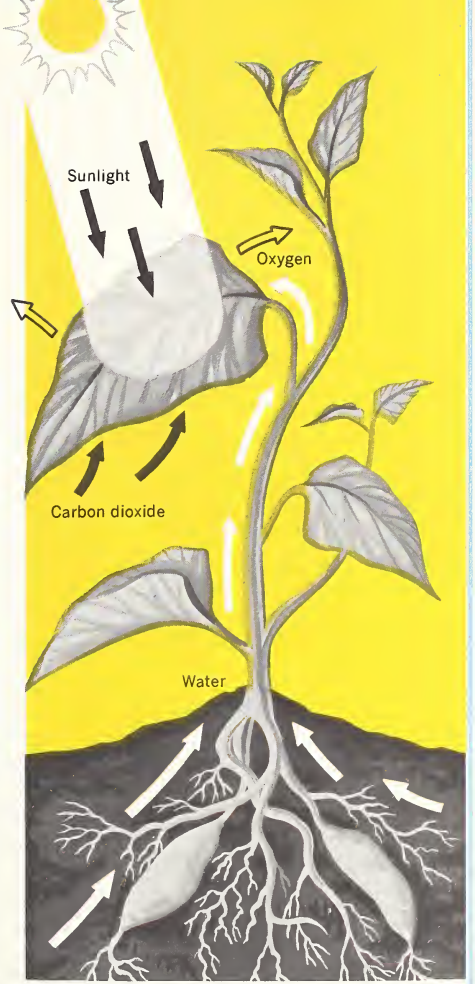
It is the light energy from sunlight that the green plant uses. You could say that the food you eat has the energy of sunlight in it, which is captured by the green plants. Can you trace the energy you use back to the sun through a green plant?

Let's review. Chlorophyll in green plants makes it possible for the plant to use the energy of sunlight to make food from materials in soil and air. You, in turn, get your energy from plants, or from animals that eat plants.

Now let's find out what kind of food a green plant makes.

The Food Green Plants Make

The food that green plants make is sugar. The making of sugar by green plants is called **photosynthesis** (foh-tuh-SIN-thuh-siss). The word photosynthesis comes from two Greek words—*photos,* meaning "light," and *synthesis,* meaning "putting together." During photosynthesis, **carbon dioxide,**



How do green plants get the materials they need to make food? What else does the picture show?

Chlorophyll is the chemical that controls food-making in plants.

Developing the Lesson: To make the distinction between green and nongreen plants (autotrophs and heterotrophs), hold up a mushroom and ask if it is a plant. As the text indicates, many plants are not green. Bacteria and fungi, which are frequently considered to be plants, do not have any green chlorophyll in them. (Some biologists place these lower forms of life in a kingdom of their own with lower protozoans. They call this kingdom the Protists.)

Follow-Up: The leaves of most plants are arranged so that they are in the most favorable position for receiving sunlight. Observe this in the plants in your classroom. Take a trip around the school grounds and look for this feature on different trees and bushes.

To observe this phenomenon over a longer period of time, plant two identical shoe boxes of grass seed and place them on the window sill. When the leaf shoots appear, cover one box completely except for a small hole facing the window. Observe daily how the leaves turn themselves toward the sunlight.

TEACHING SUGGESTIONS
(pp. 64–65)

LESSON: What basic food is made in green plants?

Background: Review the background material given on the previous page, paying particular attention to the summary equation. Keep in mind that hundreds of chemical reactions take place between the right side and the left side of your equation. The equation only gives a hint as to the first and last step.

Learnings to Be Developed:

Water and carbon dioxide are the ingredients for photosynthesis.

A simple sugar is the basic food produced by photosynthesis.

Developing the Lesson:

- *What raw materials are needed by plants for food making?* (Carbon dioxide and water.)
- *What energy is used to do the work of manufacturing?* (Sunlight.)
- *What role does chlorophyll play?* (It seems to trap the energy of sunlight and use it for chemical work.)
- *What is the food product first made by a plant?* (A simple sugar called glucose.)

which is a gas, and water are *put together in light* to make a kind of sugar.

The sugar made by green plants is not the sugar you use at home. Although it is white, it is not nearly as sweet. It is the same sugar that you have in every living cell of your body. This sugar is called **glucose** (GLOO-kohss). All the glucose in the living cells of your body comes from food made by green plants.

Glucose is used by the plant to make other kinds of food. One of these foods is starch. How can we

PATHFINDERS IN SCIENCE

Jan Ingen-Housz

(1730–1799) Holland

Jan Ingen-Housz (ING-un-howss) was a medical doctor whose hobby was science. He was the first to investigate the process of photosynthesis.

In the summer of 1778, Ingen-Housz visited England. During the next three months he did 500 experiments. These experiments were remarkable. However, they were not really appreciated at the time because people did not fully understand their importance. Today's scientists believe that Ingen-Housz's experiments were the beginning of the modern study of photosynthesis.

Ingen-Housz published the results of his experiments in 1779 as "Experiments on Vegetables, Discovering Their Great Power of Purifying the Common Air in the Sunshine, and of Injuring it in the Shade and at Night." This is what Ingen-Housz wrote:

"I was not long engaged in this enquiry before I saw a most important scene opened to my view: I observed, that plants not only . . . correct bad air in six or ten days, by growing in it, . . . but that they perform this . . . in a few hours; . . . owing to the . . . influence of the light of the sun upon the plant. I found that plants . . . pour down continually . . . a shower of this . . . air, which . . . contributes to render it more fit for animal life; that this operation is far from being carried on constantly, but begins only after the sun has for some time made his appearance above the horizon, and has, by his influence, prepared the plants

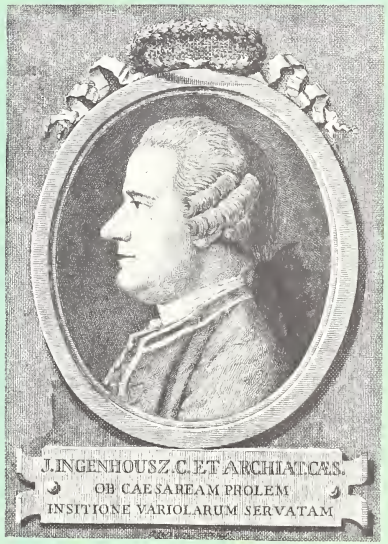
find out if starch is made in the green leaf? You can find out by placing a drop of iodine on the leaf. Iodine turns from brown to blue if there is starch. But the leaf that you will use is green, so you may not be able to see a blue color in the leaf. If you take off some of the green coloring, then you could test it for starch.

Did you ever get a green stain on your clothes after sitting in the grass? Some of the chlorophyll from the grass rubbed off. Do you think you can rub the chlorophyll off a leaf?

to begin anew their beneficial operation upon the air, and thus upon the animal creation, which was stopt during the darkness of the night. . . ."

The experiments which Ingen-Housz did showed that the green parts of plants perform the process of photosynthesis. He showed that green plants give off oxygen in sunlight and carbon dioxide in the shade and at night. He even observed chlorophyll in the green leaf.

One of today's leading researchers in photosynthesis, Dr. Eugene I. Rabinowitz, has said, "In photosynthesis, we are like travelers in an unknown country around whom the early morning fog slowly begins to rise, vaguely revealing the outlines of the landscape. It will be thrilling to see it in bright daylight." Jan Ingen-Housz was the first pathfinder to explore this unknown country.



Background: Jan Ingen-Housz was born at Breda on December 8, 1730, and died at Bowood, Wiltshire, England, on September 7, 1799. He received his medical education at the universities of Louvain and Leiden.

In the late 1760's, Joseph Priestley had begun his experiments with gases. He lived next door to a brewery and discovered that the fermenting malt produced a gas that was heavier than air, dissolved somewhat in water, and put out flames. This gas was carbon dioxide. In 1774, Priestley discovered another gas, one that burned brilliantly. He also discovered that plants released this gas into the air. This gas was oxygen.

Ingen-Housz was interested in Priestley's discoveries. He conducted the experiments that led to his discovery that green plants take up carbon dioxide and give off oxygen in the light, but that they take up oxygen and give off carbon dioxide in the dark. This was the first indication that light in some way played a role in the life processes of plants. It was left to a German botanist, Julius von Sachs, to discover in 1865 that it was the chlorophyll in plants that combined the light with these gases to form plant nutrients.

TEACHING SUGGESTIONS
(pp. 66–67)

LESSON: How can chlorophyll be removed in order to study starch?

Background: Most children like to perform experiments in which color is involved, and plant materials offer many opportunities for such activity. Plant colors are all about us. The produce shelf in the supermarket is a riot of color. Our fruits, flowers, vegetables, and wine are frequently judged by their color. Plants turn yellow in a light deficiency. Flowers fade, that is, they lose their color. Some leaves turn red in the fall.

There are two categories of colors in plants:

1. *The plastid pigments* are not water soluble and are found in organized plastids. These are mainly the chlorophylls (green) and the carotinoids (yellow). The green in spinach and the orange in carrots belong in this category.

2. *The sap pigments* are water soluble and are dissolved in the sap of the cells. These are chiefly the anthocyanins (red, purple, blue) and the anthoxanthins (yellow, orange). The purple in grapes and the brown in cured tobacco belong here.

EXPERIMENT

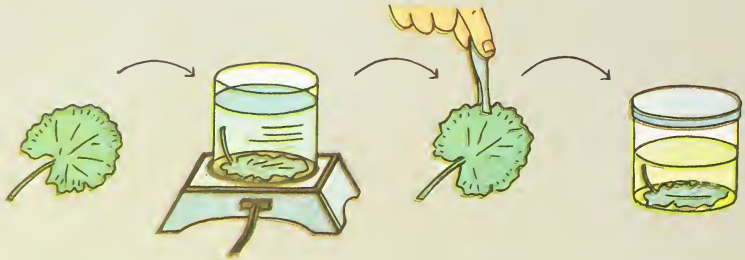
How Can Chlorophyll Be Removed from a Green Leaf?

What You Will Need

wide-mouthed glass jar and cover	small glass bottle	green leaves (coleus or geranium)
	hot plate	
	rubbing alcohol	

How You Can Find Out

1. Soften the leaves by boiling them in water.
2. Put some leaves in the jar and cover them with alcohol.
3. The next day, pour the alcohol into a small glass bottle.



Questions to Think About

1. What is the color of the leaves?
2. What is the color of the alcohol?
3. How did the chlorophyll from the leaves get into the alcohol?

The chlorophyll is now removed, and the leaves may now be tested for starch. Wash the leaves in water to get out any alcohol. Next drop some iodine on them with a medicine dropper. What happens? How can you find out if there is starch in a potato, in an apple, in a piece of bread, or in wheat flour?

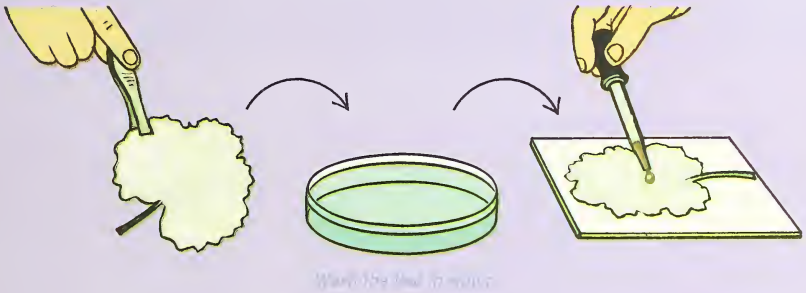
Do Green and Non-Green Parts of Leaves Have the Same Amount of Starch?

What You Will Need

iodine
rubbing alcohol
tweezers
coleus leaf (or any other leaf that is partly green and partly white)

How You Can Find Out

1. Remove the chlorophyll and wash the leaf.
2. Drop iodine on the part of the leaf that was green and on the part of the leaf that was white.



Questions to Think About

1. Does it look as if the green part and the white part of the leaf have the same amount of starch?
2. What does this experiment show?

Now try doing this. Take a leaf from a plant that has been standing in the sunlight for a few hours and test it for starch.

Do you think starch will dissolve in water? How can you find out? Try dissolving cornstarch or the kind of starch used for starching clothes.

Learnings to Be Developed:

Chlorophyll can be dissolved from a leaf by using alcohol.

Starch can be found in the leaf.

Developing the Lesson: Proceed with the experiments and discuss the *Questions to Think About* (p. 66).

1. The leaf is a grayish-green after boiling.

2. The alcohol is green.

3. Chlorophyll is soluble in alcohol. The water-boiling process was designed to break the cellulose walls of the cells and the chloroplasts.

Background: Proceed to the experiment on page 67 and then discuss the *Questions to Think About* section.

1. Depending on the degree of whiteness of the nongreen areas, you should find more evidence of starch (blue color) in the green area than in the white.

2. This experiment indicates that the green color is associated with the presence of starch. Though the experiment does not *prove* that chlorophyll was the agent for starch making, we know this is so from more sophisticated experiments. The mere presence of starch near chlorophyll is not a proof; it is a clue.

EXPERIMENT

Do Green Plants Need Light to Make Food?

What You Will Need

green plant (coleus or geranium)
iodine
water
rubbing alcohol

How You Can Find Out

1. Test two or more leaves of the plant for starch.
2. Water the plant well.
3. Place the plant in a closet for two days.
4. After two days, test two or more leaves for starch.

Questions to Think About

1. Which leaves have less starch in them? What does this show?
2. Why can some plants grow in shady places?

TEACHING SUGGESTIONS
(pp. 68–69)

Background: The following material provides the answers to the *Questions to Think About* section on page 68.

1. The leaves left in a dark place are deficient in starch. Green plants need light to make food.

2. There can be several answers to this question: Starch requirements may not be as high. Rates of photosynthesis may be more rapid, and hence less light is needed. The amounts of chlorophyll in these plants may be greater.

LESSON: What does the structure of a plant contribute to the food-making process?

Background: The leaves, branches, stems, and roots of plants exhibit a unity of function associated with food making, storing, and transport.

Learnings to Be Developed: The structure of green plants makes it possible for them to carry on food-making processes.

Developing the Lesson: Obtain a chart of a leaf cross section.

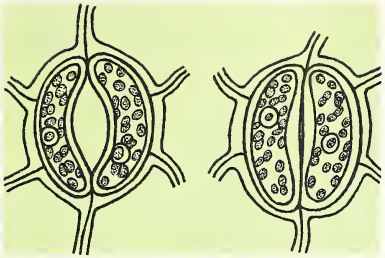
- *How do the various parts of the leaf help in the manufacture of sugar?*

Besides starch, green plants also make proteins and oils from glucose. Soybeans are rich in proteins. Rub a peanut between your fingers. How does it feel? Peanuts and cottonseed have much oil in them.

How Plants Use Food

Some of the food that the plant makes is used by the plant itself. It uses the food in the same ways that your body uses food. It uses food as fuel for energy. It uses food to grow new cells and to repair old cells. Food that is not used right away may be stored in the plant's stem, roots, and other parts. So the next time you eat celery, remember that you are eating food that the celery plant stored in its stem. And when you eat a carrot, you are eating food stored in the root of a carrot plant. Now do you see that the food the green plant makes for itself is the same food that you use for energy, growth, and repair of your body?

Let's review. Green leaves use the energy from sunlight to make glucose. Some of this energy is stored in the glucose. Glucose and the foods made from it contain energy from sunlight.



Tiny openings on the underside of plant leaves.

Leaves

You learned that the green plant needs carbon dioxide and water to make glucose. The carbon dioxide that the plant needs enters the plant through the *leaves*.

On all leaves there are hundreds of tiny openings. These openings are about 2,000 times smaller than a pinhole. It is through these openings that air enters the leaves. The plant uses the carbon dioxide that is in the air. On many leaves, there are many more openings on the underside of the leaf than on the upper side. Can you tell why? However, the leaves of a water lily have most of the openings on the upper side. Can you tell why?

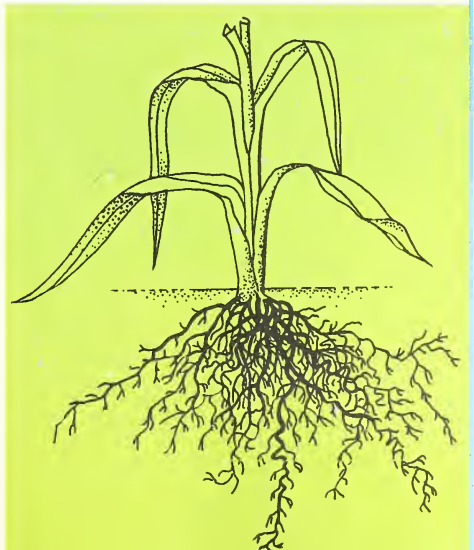
We have been studying what happens in just one part of a green plant—the leaf. Let's now take a closer look at some other parts of the plant.

Roots

Now let's find out how the green plant gets water. The water it needs to make food and grow is in the soil. If you dig up a plant, you will find that there are many "branches" on the part that grows in the soil. These branches are called *roots*. They spread out into the soil and absorb, or soak up, the water that is needed by the plant.

When you plant seeds, tiny roots soon spread out into the soil and absorb the water needed by the plant. You can see how this happens.

How do roots spread out in the soil? How does this arrangement help them take in water?



Point out functions of each of the six structures shown. Whether or not you use the name for each structure will depend on your own particular teaching situation.

1. STOMATES
   Function: Openings which admit CO_2 and allow exit of O_2 and H_2O. Usually on bottom of leaf, guard cells control these openings.
2. EPIDERMAL CELLS
   Function: Translucent outer layer permits sunlight to penetrate to lower cell layers.
3. PALISADE CELLS
   Function: Contain chloroplasts—oval bodies possessing chlorophyll. Sugar is produced inside these cells with the aid of chlorophyll.
4. SPONGY CELLS
   Function: Same function as palisade cells but more loosely arranged.
5. VEINS
   Function: Tubes which carry water and minerals from the stem and roots to the palisade and spongy cells.
6. AIR SPACES
   Function: Surround the spongy layer. Store CO_2 needed by cells.

EXPERIMENT

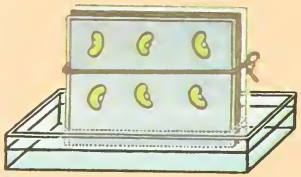
How Do Roots Grow?

What You Will Need

corn or bean seeds pan of water two pieces of glass
blotting paper

How You Can Find Out

1. Soak the corn or bean seeds overnight.
2. Wet the blotting paper and place the seeds on it.
3. Put the blotting paper between two pieces of glass.
4. Put the pieces of glass in a pan of water so that the blotting paper will be kept wet.
5. Let the glass remain in the pan for several days.



Questions to Think About

1. Why do you need to use blotting paper?
2. What do the roots look like?

You can also watch roots grow if you put stems or cuttings of certain kinds of plants in water. Your mother may put pieces of ivy or other plants in water before she plants them in soil. This is called "rooting" the plants. If a glass container is used, you can see what happens after the plant has been left in the water for a while.

Have you ever put part of a carrot or a sweet potato in water? This is another way to watch roots grow. What is the chief difference between the experiments on pages 70 and 71?

TEACHING SUGGESTIONS
(pp. 70–71)

LESSON: How do roots grow?

Background: The two experiments on roots will take some time to yield results. It is suggested that the teacher do some preliminary soaking and growing before the experiments are begun in class in order to avoid needless delay.

Learnings to Be Developed: The structure of roots helps the plant absorb moisture.

Developing the Lesson: While the two experiments are in progress, have the children examine root systems of various plants—grass, potted plants, weeds, etc. Provide them with hand lenses. Point out the presence of a root cap at the very tip of a root. This protects the growing tip from injury. Have the children observe the presence of root hairs above the root tip. Discuss how these hairs increase the number of cells exposed to soil water, and how this benefits the plant. A chart showing a picture of a root and root hairs would be useful here.

EXPERIMENT

How Do Roots Grow?

What You Will Need

a carrot or a sweet potato pan of water

How You Can Find Out

1. Cut off about an inch from the top of a carrot or from one end of a sweet potato.
2. Put this piece in a pan of water with the cut end of the piece down.
3. Do not cover the whole piece with water.

Questions to Think About

1. What is the first thing to grow out of the plant?
2. How does the piece of plant get water?
3. How long did it take for roots to grow?

If you look at the roots of plants with a magnifying glass, you will see tiny root hairs that spread out into the soil. You can see these root hairs on the bean plants or the corn plants you have been observing. They absorb water and minerals from the soil.

Stems

From the roots, the water and minerals travel up the *stem*. You cannot see the minerals in the water. You cannot see the water and minerals traveling through the stem, unless you add some coloring to the water.

If possible, permit children to uproot a bunch of grass to compare the root system with that of a beet or a carrot. They will see that the grass has a long fibrous root system, while the beet or carrot has a large fleshy taproot.

Follow-Up: Summarize the results of the experiments by asking:

- *Of what importance are roots to the plant?*

Responses should include the facts that roots absorb water and dissolved minerals from the soil, they allow these substances to be conducted to the stem, and some roots are used for storage of food produced by the leaves during photosynthesis.

Have the pupils make a collection of plants showing various types of root systems—grass, cactus, dandelion, crab grass, tomato, potato, etc. Ask them to tell what the differences are among the root systems and how these differences enable the plants to survive in various kinds of environments.

EXPERIMENT

How Do Water and Minerals Travel Through the Stem?

What You Will Need

water	celery	red or blue
knife	glass jar	vegetable coloring

How You Can Find Out

1. Mix the red or blue vegetable coloring with water.
2. Put a piece of celery into the colored water.
3. Cut off the end of the celery *while it is under the water.*
4. Place the jar of colored water in sunlight for several hours.

Questions to Think About

1. What happens to the red or blue coloring mixed with water?
2. How does water from the soil travel up the plant?

Stems also hold up the plant. Have you ever seen garden plants drooping in the sun? This may happen when plants are losing water faster than they can get it from the soil. This shows that they need water to help support them.

Stems also carry the food made in the leaves to other parts of the plant. Just as the cells of your entire body need food to live and grow, so do the cells of the entire plant. All living things must have food.

TEACHING SUGGESTIONS
(p. 72)

LESSON: What do the stems of plants do?

Background: The stem of a plant plays at least two major roles. First, it provides support for the leaves and tissues involved in photosynthesis. Second, it carries, or transports, materials from leaves to roots and from roots to leaves.

The materials transported by stems are of two types: water plus dissolved mineral salts, which are taken in by the roots; and sugars, formed in the leaves.

Learnings to Be Developed: Stems of green plants provide support for the plant and a transportation system for dissolved materials.

Developing the Lesson: The activities described in the experiment are simple, and results should be observable to the children after a half hour or so.

Background: The following material will provide the answers to the *Questions to Think About* section.

1. The colored fluid moves up the small vessels or tubes in the celery.

2. The water, in thin, almost microscopic tubes, is used up at the top of a plant, and is continually being drawn up the plant.

Green Plants Store Food

Some of the food made by a green plant is used by the plant to live and grow. The rest is stored in the plant's roots or stem or seeds.

Some plants, such as the carrot, the sweet potato, the beet, and the radish, store food in their roots. When you eat these vegetables, you are eating the food that the plants have stored in their roots.

Some plants store food in underground stems. For example, the white potato is really the underground stem of the potato plant. It contains the starchy food that the green part of the potato plant makes. How can you be sure that the potato is storing starch? Is it also storing other foods?

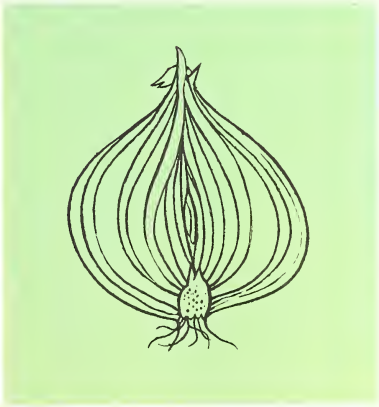
The **bulb** in plants such as onions and tulips is made up of leaves growing around each other. You can see them if you cut an onion in half from top to bottom. The growing part of the bulb is in the center. Around it are very thick leaves. They are not green, as most leaves are. They do not make food, as green leaves do. But they do store food.

If you put an onion in water in a warm, dark place for several days, you can watch green leaves grow out of the top. The food stored in the thick leaves of the bulb helps them grow.

All plants store some food in their seeds. When seeds are planted, this food keeps the new plant alive inside the seed until it can make its own food. You saw how this happened when you planted bean and corn seeds.

We use many seeds for our own food. We use the seeds of beans, peas, and corn. We eat the seeds and the seed containers, or fruits, of other plants, such as cucumbers, eggplants, peppers, squash, and tomatoes.

How does the stored food in the leaves of the bulb help the young plant to grow and develop?



The onion stores a simple sugar called sucrose. Most root foods are rich in starch.

TEACHING SUGGESTIONS
(p. 73)

LESSON: What do plants do with excess foods?

Background: Every living cell in a plant requires food energy. The sugar manufactured in the leaves is used by these cells and the excess is stored for future use. In the corn plant, for example, the food made in the leaves is used as follows:

25% to supply current energy needs
50% for growth and repair
25% stored

The stored foods are usually in the form of sugars and starches, proteins, fats, and oils. All of these are transformed from simple sugars within the plant itself.

Learnings to Be Developed: Excess food supplies are stored in various parts of plants.

Developing the Lesson: Begin by asking the children what parts of plants they have eaten recently.

Roots: onions, beets, sweet potatoes, turnips
Leaves: lettuce, cabbage, spinach
Seeds: oats, corn, rice, wheat
Fruits: tomato, apple
Stems: sugar cane, bamboo shoots

TEACHING SUGGESTIONS

(pp. 74–75)

Background: This material will assist you with the questions developed in *Using What You Have Learned.*

1. Fruit salad: direct from plant
   Chicken: ate grain food (seeds)
   Celery: stem and leaves
   Olive: a fruit
   Roast beef: steers ate seeds and grass
   Potato: a tuber or storage part
   Peas: seeds of plant
   Carrots: roots
   Butter: cows ate grass and feed
   Rolls: grain (seeds)
   Lettuce: leaves
   Tomato: fruit
   Cake: seeds of wheat
   Chocolate: fruit of cocoa plant
   Milk: cow ate grass and plant fodder

2. Seeds: corn, lima beans, peas, peanuts
Seed containers: eggplant, tomatoes, cucumbers, squash
Lettuce and cabbage are leaves.
Turnips and carrots are roots.

3. The cause could be lack of sunlight, too little or too much water, mineral deficiency, excessive heat or cold, or a disease. The most common cause is lack of sunlight.

4. Once the green parts are visible, you know the plant has used up most of the stored food in the

Using What You Have Learned

1. Susan and her parents went to her grandmother's farm for Sunday dinner. They all ate these things:

fruit salad	peas and carrots
chicken soup	rolls and butter
celery and olives	lettuce and tomato salad
roast beef	chocolate layer cake
baked potatoes	milk

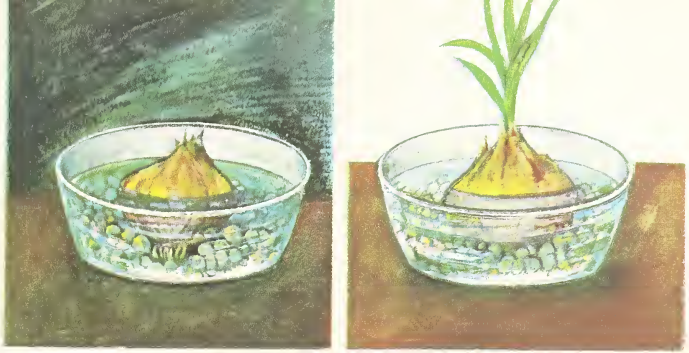
At the end of dinner, Susan said, "We couldn't have had a thing to eat today if it were not for green plants." Her grandmother asked Susan to explain. How might Susan trace each food they ate back to green plants?

2. We use many kinds of seeds for food. We also eat the seed containers, or fruits, of some plants. Look at the list of plants below. Pick out the seeds that you eat. Pick out the seed containers that you eat. Which foods on this list are not seeds or seed containers?

lettuce	eggplant	carrots
corn	tomatoes	cucumbers
lima beans	cabbage	peas
squash	turnips	peanuts

3. Suppose that you have a house plant that was healthy and green when you got it. Suddenly it begins to droop, and a few leaves begin to turn yellow. What may be the causes? What might you do to save the plant? What will you try first? Why?

4. You can raise plants such as the narcissus and hyacinth from bulbs. Plant the bulbs in a bowl, with pebbles to hold



Why do bulbs begin growing better in dark places than in sunny places? Why shouldn't you completely cover the bulb with water?

them. If you plant more than one in a bowl, do not let the bulbs touch each other. Use enough water to come up to the bottom of the bulbs.

Put two or three pieces of charcoal in the bottom of the bowl. They will keep the water from smelling unpleasant when the brown leaves of the bulbs begin to rot.

Put the bulbs in a dark place until they begin to grow. Then put them in the sun and water them. Why can you not let them go on growing in the dark?

5. Get four flowerpots of the same size and number them. Plant five bean seeds in each one. Put flowerpot 1 on the windowsill, and water it every day. Put flowerpot 2 next to flowerpot 1, but do not water it. Put flowerpot 3 in a closet, and water it every day. Put flowerpot 4 in a closet, but do not water it.

Keep a daily chart, for three weeks, of how much each plant grows. Which plant grows best? What do plants need to grow?

bulb. Sunlight is needed for manufacturing food in the green parts.

5. Results of charts will vary but the plant in flowerpot will grow best. Growth needs are: air with carbon dioxide, mineral salts in the soil, moisture, medium heat, light.

ADDITIONAL ACTIVITIES:

Children can grow many different plants in the classroom. They might begin with cuttings of beet tops, carrot tops, radishes, and turnips. Have them remove the leaves and place cuttings in shallow dishes of water containing clean pebbles or gravel. Add water as needed.

To grow white or sweet potatoes, partially submerge the cutting in a glass of water. Use toothpicks to prevent complete submergence.

Avocado seeds should be buried halfway in moist soil. Add water to keep soil moist.

To grow citrus fruits, wash the seeds and plant a few in a shallow pot of soil. Water once every two or three days.

Children may also wish to plant bulbs or cuttings from twigs of plants such as pussy willow and forsythia. Others may plant pea or bean seeds in paper cups of soil.

TEACHING SUGGESTIONS
(pp. 76–77)

● **LESSON:** What adaptations do plants have to survive extremes of climate?

Background: The key to plant survival is adaptation. Following are some of the ways in which different plants are adapted to different factors.

Cactus stems contain many water storage cells. Elodea, the common aquarium plant, can live submerged. Spanish moss grows on trees and takes water from the moisture-laden air of the tropical forest.

Grasses, needing a great deal of light, do not grow under trees or in the woods but cover vast areas of "grasslands" where there are no trees to shade them out. Certain seeds like those of Grand Rapids lettuce need light to germinate, while others are inhibited by such exposure. They grow in the areas that meet these needs. Cotton, requiring 200 growing days, grows only in tropical or semitropical regions. Peas, potatoes, radishes, and other such vegetables need less than 90 growing days, and grow in some areas of Alaska.

In all this discussion concerning adaptation, you must be careful

Green Plants—How They Survive

There are plants to be found on almost every part of our planet. There are plants on the coldest parts of the earth. There are plants on the warmest parts of the earth. And there are plants living on parts of the earth where there are many changes in temperature during the year. These plants are able to live through very hot temperatures in the summer and below-freezing temperatures in the winter.

Some Plants Survive the Winter

Most trees and shrubs bloom and grow during the months of spring, summer, and fall. When winter comes, the leaves fall and the food made within them moves to those parts of the plants that are not hurt by freezing. During these cold months, there is very little growth.

There are, however, some plants that remain green during the coldest days of winter. The pine tree is one such plant. A pine tree is known as a woody plant. Can you name other plants that are woody? Even though some plants stay green during the winter, they do not grow as rapidly or make as much food as they do in warmer months.

Many plants that are not woody, such as some garden plants, only partly die in the winter. The parts that die are all above the ground. But other parts of the plant, below the ground,

How does the pine tree survive the winter months? What happens to the tulip during the winter months? What happens to each of them when summer comes?

remain alive. In spring, the parts above the ground appear again. Can you tell which parts of these plants stay alive during the winter? If only the parts of the plant below ground remain alive in winter, do you think the plant is better able to survive? Why?

Some Plants Can Survive with Little Water

Plants and animals need water to live. Animals can move to another place when water becomes scarce. Plants cannot do this. How, then, do plants survive?

The cactus is a plant that grows in very hot, dry places. A cactus plant can live for long periods of time without rain. How is the cactus plant able to do this? Look at the picture on this page. Do you see any leaves on the cactus plant? Look at the stem. See how wide it is. The roots are very close to the surface of the ground. When it rains, the roots can quickly take the water the plant needs and store it in the stem. The stem can hold a supply of water lasting many months.

Some plants grow in soil that does not hold a great deal of water. Plants that live in this kind of soil do not lose much water. Do you know why? Pine trees can live in sandy soil, which holds little water. Pine trees have narrow leaves. How does this help them to save water?

You have been reading about some of the ways plants are able to live through heat, cold, and dryness. Farmers who grow plants for food cannot depend on these ways only. Can you tell why this is so?

Some cacti can live for more than a year on just one heavy rainfall. How is this possible?

To demonstrate surface loss of water on two areas, take a test tube half full of water and pour the water on a blotter. Half fill the test tube again. Then set aside both tube and blotter. Have class check them daily and compare the times needed for complete water loss.

not to give children the impression that plants purposely change in order to survive. Plants have no intentions. The adaptations are hereditary, and the cause of the initial adaptation can only be guessed at.

Learnings to Be Developed:

Green plants are adapted to different environments.

Various structures in plants compensate for extremes of moisture and temperature.

Developing the Lesson: Ask pupils the following question.

- *Does a pine tree have any leaves?* (Yes. The needles are modified leaves. They have chlorophyll, stomates, and veins.)

Bring in some pine needles for class examination. Crush some of them to stain white paper and show chlorophyll. Examine some cut needles under a microscope or hand lens.

The structure of the pine tree's leaves reduces water loss during the winter season. Loss of water through the leaves is reduced by a lessening of the surface area. This reduced surface area is also a protection against extremes of temperature.

TEACHING SUGGESTIONS
(p. 78)

LESSON: How does man protect plants against the cold?

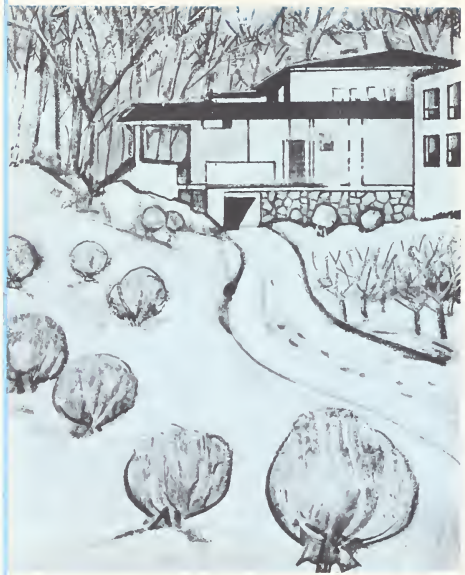
Learnings to Be Developed: Man can change a plant's environment for his own purposes.

Developing the Lesson: If a greenhouse is nearby, a visit would be ideal at this time to help pupils understand the functions of such a structure. Find out the specific purpose of the greenhouse. Determine whether it is used to get a head start on spring planting, to produce flowers out of season, or to produce foods out of season.

A small greenhouse could be easily constructed in the classroom from a wood frame and a sheet of plastic film. Place it on a sunny window ledge and have pupils study temperature and moisture conditions daily. If sturdily built, it could be a year-long center of classroom interest, as well as a practical place for growing experimental plants.

ADDITIONAL ACTIVITIES:

Begin a project in collaboration with the P.T.A. to build a small school greenhouse for permanent use. Local carpenters, glaziers, and masons might undertake such a project in the interests of the community.



One way to protect shrubs from the cold is shown here. How does this method work?

Man Protects Plants

Because we depend on plants for our food, we must depend on the farmers who raise crops for food. They, in turn, must grow healthy plants to earn a livelihood. They must do everything they can to make certain their plants stay healthy.

Farmers and flower growers have learned many ways to protect plants. They have learned these ways from plant scientists, who keep finding new and better ways to protect plants from heat, cold, diseases, and animals.

Plant scientists help not only the farmer but also the gardeners who grow and sell flowers. Scientists help people who enjoy growing flowers and vegetables for fun and beauty. Let us now find out how scientists help people to protect plants.

Protecting Plants Against Heat and Cold

Have you ever seen young plants in a garden with baskets or paper coverings over them? This is one way some young plants are protected from the hot sun. They are shaded until their roots can get the water they need.

Have you ever visited a greenhouse where some plants are grown until it is warm enough to plant them outdoors? Cabbage and tomato plants are grown in greenhouses. The sun shines through the glass roof and sides of the greenhouse. The glass protects the plants from cold and storms, but it lets the sun shine on the young plants. The sun heats the soil in the greenhouse. How does this heat the air?

Many plants are kept in greenhouses until it is warm enough for them to be planted outdoors.

These fungi are found on the sides of trees. Can you find out the name of the fungi?

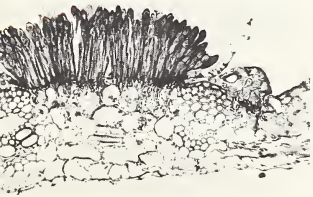
Protecting Plants Against Disease

You have heard of the bacteria which sometimes cause disease. Bacteria belong to the group of plants called **fungi** (FUN-jy). Fungi are plants that do not have chlorophyll. They cannot make their own food. They must feed on animals and on other plants. They are so tiny you need a microscope to see them.

Some bacteria are useful in the garden. They help to put minerals containing nitrogen into the soil. Plants need nitrogen to live and grow.

Other bacteria are harmful to plants. They cause plant diseases. Have you ever seen gardens where some plants have withered and died from plant diseases? Plant diseases can ruin valuable crops on farms.

On the left are wheat rust spores as they look under a microscope. In the center you see the spores on a wheat plant. On the right is a fungus that affects rose plants, called black spot smut. Both rust and smut are diseases that destroy plants.



TEACHING SUGGESTIONS
(pp. 79–80)

LESSON: Do plants become diseased?

Background: Disease in plants is most simply defined as "any deviation from a normal condition." Generally, the causative agent is an environmental factor or a living organism. Human and animal diseases are well known and publicized, but most people are unaware of the extent and economic impact of plant disease. It took a tragic event, the Irish famine in the 19th century, to make man realize the need for a knowledge of plant diseases. Ireland had become almost entirely dependent on potatoes for food, but for two years, 1845 and 1846, the potato crop was almost completely destroyed by the late blight. In the resulting devastation, Ireland lost one-third of its population. A million people died of starvation and related complications, and another million and a half emigrated. Plant diseases are most assuredly a concern of man.

Learnings to Be Developed: Man has developed some controls over plant diseases.

Developing the Lesson: Ask the children if anyone has seen a tree limb sawed off. Ask if he noticed whether anything was done to the

stump, or "wound," that was left on the tree. Proper management requires that the wound be painted with a barrier material. The barrier blocks the entrance of disease organisms or insect carriers from the exposed living tissue of the tree. In the same way, a cut finger which is washed with a mild antiseptic is then bandaged or "dressed" to keep it clean.

Now ask the children how a disease organism, which can't move about by itself and which is not carried by an insect, could get into the wound in the tree. Help them understand that it is carried by the air. Discuss how air spreads disease. Explain that some of the diseases of plants are caused by a group of nongreen plants called fungi. One type of fungi is mold. Molds are propagated by individual microscopic bodies called spores, which are everywhere in the air.

ADDITIONAL ACTIVITIES:

Have children investigate and report on the chemical treatments used to prevent disease in plants, such as dusting, spraying, fungicides, etc. With the aid of newspaper and magazine articles, let them discuss the pros and cons of these methods.

On the left is the apple borer, which destroys apple crops. On the right are plant galls, which cause plants to lose food materials. These galls may be caused by bacteria, fungi, viruses, or insects. Have you ever seen such galls on plants?

Closeup of apple's skin shows damage caused by apple borers.

There are many kinds of diseases that attack plants. Some diseases attack fruits and vegetables. Others attack flowers. Some attack our crop plants and forest trees.

There are ways we can keep diseases from attacking plants. Scientists have made sprays and powders that kill the bacteria before they can do any harm. Other sprays kill the insects that carry the bacteria from the diseased plants to the healthy ones. Farmers, aided by state and local agricultural agencies, know exactly the right time to spray.

Once a disease attacks a plant, the plant becomes dangerous to the healthy plants around it. Plant growers help plants get rid of some diseases by spraying the plants or by using a powder on them. Often they remove and burn the diseased parts of the plants.

Expose a piece of damp white bread to the air. Then put it in a glass dish and cover it with transparent material (glass or plastic film). Examine it daily as the mold begins to form, looking at the mold under a magnifying glass. The same experiment can be done with mold growing on a fruit. Oranges and grapes are the most likely possibilities.

Protecting Plants Against Weeds

If you have a garden, you know that plants must also be protected from **weeds.** Weeds are plants that grow where they are not wanted. Some weeds you may know about are crab grass and dandelions. Can you name some other weeds? Weeds crowd out other plants. They usually grow faster than the useful plants. Weeds will grow in your garden if you are not careful. They will use some of the water and minerals that your garden plants need.

Some weeds grow so tall that they will keep garden plants from getting the light they need. You will have to get rid of them before they get a chance to produce seeds. If you do not, still more weeds will grow. What are some ways to get rid of weeds?

These plants are all weeds. Can you name them? How will you go about finding their names?

TEACHING SUGGESTIONS
(pp. 81–82)

● **LESSON:** How does man eliminate weeds?

Background: The term *weed* is a relative one, because many plants may be useful, beautiful, or interesting in some places, but obnoxious elsewhere. White clover is desirable on some lawns, but is a pest in strawberry beds.

Most weeds are not only useless and unsightly, but are a hindrance to the crop grower in the following ways: They compete with the crop for minerals and moisture; they reduce the yield of the crop; they provide hosts for diseases that attack crops and shelter for harmful insects; and they increase the labor of cultivation and harvesting.

Learnings to Be Developed:

Weeds rob plants of nourishment.

Weeds can be controlled.

Developing the Lesson: Encourage children to talk about their own experiences in getting rid of weeds. Children in agricultural areas will be full of such experiences, while those in suburban areas will undoubtedly be able to provide information about crab grass and other lawn and garden weeds. Children in an urban classroom can find weeds in

planting boxes, greenhouses, and their own potted plants.

Among the methods currently in use for controlling weeds are mechanical methods, such as pulling them out or cutting them down before they can reseed, and chemical methods, which involve poisoning the weeds. Children can investigate and report on these different methods. Some children might be interested in doing research on agricultural tools in use today. Ask them to find out which ones are primarily used for weed control.

Appoint committees to report on four principal methods for disease control in plants: (1) exclusion before planting, (2) eradication, (3) protection, (4) immunization.

If the season is right, your class might make a collection of examples of plant diseases, or collect photographs of them. Some common diseases are:

- Scorch
- Blight
- Spot
- Canker
- Rot
- Damping-off
- Wilt
- Chlorosis
- Mosaic
- Tumefaction
- Scab
- Callus

How do the three animals shown harm plants in different ways? Can you tell what each does that will harm or destroy the plants?

Protecting Plants Against Animals

There are still other enemies of plants besides weather and disease. These enemies are animals.

Some birds eat young plants. Many insects destroy leaves or fruits. Gophers or ground squirrels destroy grain, grass, young plants, and fruit trees. Rabbits gnaw away at young peach or apple trees during the cold winter.

All these animals feed on plants or seeds. Some of them, like the Japanese beetle and the tent caterpillar, are harmful and must be destroyed. Others, like the bird and rabbit, must just be kept from harming plants.

Aphids pierce leaf tissue and draw out the plant's juices with their sucking mouth parts.

In this picture you see beetle larvae, known as grubs. Grubs cause decay in many plants.

Insects damage plants in different ways. The grasshopper eats leaves, buds, bark, roots, stems, and fruits of plants. Some insects cannot chew, but they suck juices from plants. These are called sucking insects. Others, like the tent caterpillar, eat the leaves of trees.

Protecting Plants Against Harmful Insects

Insects destroy more plants than any other animals do. They destroy almost as many trees each year as forest fires. Scientists, farmers, gardeners, and people who grow flowers or vegetable gardens at home are always fighting these enemies of plants. If you want to grow flowers or vegetables, you will have to fight them, too.

In order to protect plants from harmful insects, we must first know how these insects live and grow. The way they live and grow is called their **life history.** Every plant and animal has a life history. If farmers and gardeners know the life history of harmful insects, they can find out when and how such insects can be destroyed more easily.

The gypsy moth is a harmful insect. It is harmful to many trees, especially apple trees. The mother moth lays her eggs on the leaves of an apple tree. As each egg hatches in the early spring, a little caterpillar comes out. It eats the young leaves of the apple tree and grows until its skin is too small for the rest of its body. Then it sheds its skin for a new one. It keeps on eating and growing. It grows several

TEACHING SUGGESTIONS
(pp. 83–86)

LESSON: What problems do insects present to plant life?

Background: The history of science is replete with controversy. Today we are in the midst of a great controversy concerning the use of persistent pesticides and insecticides on forest and farm to fight off attacks by insects and plant diseases.

A careful reading, or rereading, of Rachel Carson's *The Silent Spring* (Houghton Mifflin, Boston, 1962) will give the teacher an excellent background in this controversy.

Learnings to Be Developed:

Science has solved some problems of insect control.

The answers themselves are sometimes more of a problem than a solution.

Developing the Lesson:

Some insects kill plants. If we have a spray that kills those insects, shall we use it?

Most pupils will answer yes, on the assumption that killing plants is always bad. Bring out the fact here that some plants are themselves bad, in that they are bad for soil.

skins in this way. While it is eating and growing, it destroys many leaves.

Then it stops eating leaves and spins a cocoon of silk thread around itself. It stays in its cocoon until certain bodily changes occur. Then it comes out of the cocoon as a moth.

When do you think the farmer would try to destroy the gypsy moth? Would he wait until the moth comes out of the cocoon? No. Then it would be too late. The farmer sprays his apple trees in the early spring when the eggs are hatching.

The farmer sprays poison on the leaves. When the caterpillars eat the

- *If the plant is a good one—valuable as food or for industry—and we spray the plant to kill the attacking insect, what will happen to the bird that uses the insect for its food?*

Discussion should develop the possibility that the bird may die of starvation or may die of poison by eating one of the sprayed insects. Someone should present the possibility that the bird may find another source of food.

- *In place of the insects, suppose the bird feeds on the earthworms that live in the ground near the sprayed plant. What will happen?*

In this discussion, children should be helped to understand the effects of poisoning by slow accumulation. None of the earthworms were killed by the spray because each of them only absorbed a little of the poison. If the bird eats many worms, however, it will get a little poison from each one of them and eventually will die.

In a similar manner of question and discussion, determine what happens to fish in a nearby stream after heavy rains carry some of the spray into their water, killing the insect larvae on which the fish feed.

Laying eggs

Larva

Pupa

LIFE CYCLE OF THE GYPSY MOTH

Adult male

Adult female

leaves, they die. The farmer's apple trees, which are not affected by the poison, will then blossom and bear fruit unless some other enemy attacks them.

Insect sprays are poisonous. They do not always kill only the *pest*. Some sprays are so powerful that they kill almost all the wildlife when a whole region is sprayed. These sprays can also be harmful to man. People must be very careful about how they spray, how much they spray, and what kind of spray they use.

Insects such as aphids cannot be destroyed by poisoning their food. These insects suck juices that are *inside* the

Millions of locusts live underground, sucking juices from tree roots, until they develop into adults and all push their way to the surface at the same time. They molt into winged insects and slit tender twigs in which to lay eggs.

Closeup of swarming locusts

- *What can happen to cows who drink water from this stream every day?*
- *What can happen if a vegetable farmer uses the water of this stream to irrigate his vegetable crops?* (Some of the poison will accumulate in the vegetables he grows, since growing plants absorb chemicals along with water.)
- *If these vegetables are sold in the market, where will the poison finally end up?*

The answer to this question, "in man's body," will bring the children to the heart of the controversy. Explain to them that, although we do not know the long-range effects of these poisons on man, or even if there are any effects, we do know that lower forms of life are harmed and even killed by them. We also know that these persistent pesticides do accumulate in all links of the biological chain.

Children may be excited enough at this point to want a full-scale class debate on the problem. The question to be debated might be phrased as follows:

- *Should we continue to use pesticides when we are ignorant of their ultimate effect, or*

should we stop or limit their use until we find out more about them?

Before selecting teams or assigning research, children should be told something about the other side of the argument against the use of pesticides. They should know, for example, that despite the present use of pesticides, about 25 per cent of food production is lost by disease and insect destruction; and that any decrease in the use of pesticides, even for a limited time, would result in a net decrease in available food at a time of continuing population increase. Children can obtain more material for both sides of the debate from conservation groups and pesticide manufacturers.

ADDITIONAL ACTIVITIES:

Compile a list and gather samples of insects injurious to plants in your county or state. State conservation departments and land-grant colleges usually have free literature available on the local insect pests.

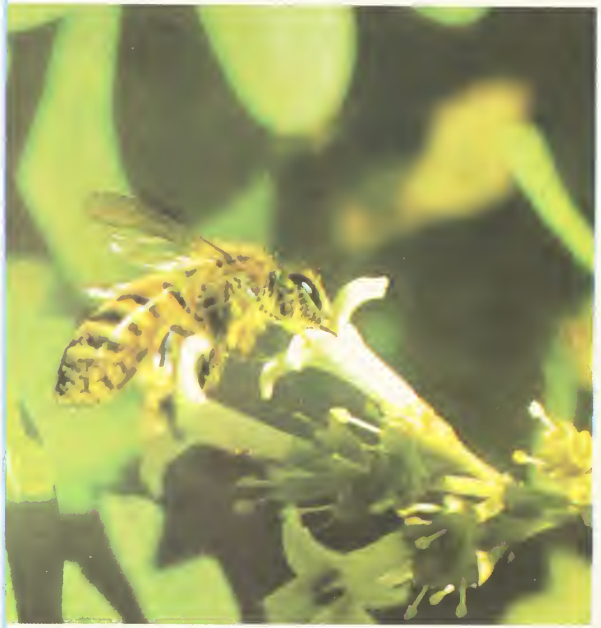
Make a display showing insects harmful to plant life and insects helpful to plant propagation. Good sources are the Yearbooks of Agriculture for 1952, *Insects,* and 1953, *Plant Diseases.*

parts of the plants. Poison sprayed on the outside of the leaves would not kill them. So the farmer uses a spray that kills the aphids when it touches them.

Sometimes the farmer traps some of the insect enemies of his plants. Japanese beetles can be trapped. You can trap them yourself. Hardware stores sell traps for them. The traps are glass jars with metal covers. The beetles can get into the jar, but they cannot escape.

Some Insects Help Plants

Even though some insects destroy plants, you should not try to kill every insect you see. Some insects help plants. Bees and other insects carry pollen from one flower to another. Pollen is needed by plants to make new plants.



The bee brushes against the parts of the flower bearing pollen and becomes dusted with the pollen, which it carries to other flowers.

The praying mantis eats grasshoppers, flies, mosquitoes, and other harmful insects. The ladybird beetle fights the cottony-cushion scale, an insect that destroys orange and lemon trees in California. Since ladybird beetles were not found in California, scientists brought them all the way from Australia to destroy the scale. The ladybird beetle is often called the ladybug.

The ichneumon (ik-NYOO-m'n) wasp lays its eggs in the skin of the larvae of some insect pests such as the sphinx moth. When the wasp larvae develop, they eat the insides of the pest larvae and then form pupas on the skin of the pest. These wasp larvae are very useful to man, for they prevent damage to plants by other insects. What other insects help plants?

Praying mantis

Ladybird beetle

TEACHING SUGGESTIONS
(pp. 87–88)

LESSON: Do some insects help plant life?

Background: In addition to pollination and the destruction of other harmful insects, some insects aid plant growth by improving the soil. The burrowing grubs of ants, beetles, and wild bees help air penetrate the soil. These insects also bring up earth from the deeper soil layers to the surface, thus improving its condition, and they aid in burying decaying vegetable matter.

The grubs, or larvae, of many wood-inhabiting beetles, ants, termites, and other minute insects are constantly at work tearing up leaves, twigs, and trunks of fallen trees, and this matter is returned to the soil to provide nutrients for other plant growth.

Insects also hasten the decay of animal bodies, and their return to the soil. In these ways they figure in the endless cycle that involves all life.

Learnings to Be Developed:

Insects help pollinate plants.

Some insects destroy other, more harmful insects.

Developing the Lesson: Pollination by bees is a familiar scene to most

children. If they have ever been in a garden, they will have noticed bees carrying pollen and nectar from one flower to another. But bees are not the only pollinators.

Pupils may mention butterflies, but they are less likely to know about the tiny fig wasp which was introduced to this country from Asia Minor during this century. These tiny insects are the sole means of fertilizing the Smyrna fig, which produces only female flowers and no pollen, from a certain inedible wild fig, which produces only male flowers with an abundance of pollen.

To introduce the idea of insects as predators, refer to the story of the ladybird beetle on page 87 of the text. Predators are the lions and tigers of the insect world. Some devour all, or a large part, of their prey. Others, such as the ant lions, merely suck the body fluids. In addition to those mentioned in the text, the predatory insects of greatest economic importance are the dragonflies, damsel flies, aphis lions, ground beetles, and syrphid flies. Among the many other predators are the ant lions or doodlebugs, robber flies, snipe flies, tiger beetles, wasps, and ants.

The woodpecker's stiff tail acts as a brace. Its deeply curved claws clutch the rough tree bark. Its beak is as hard as a chisel. Powerful muscles in the head and neck of the woodpecker enable it to drive its beak with hammer-like blows into the tree. A long tongue with pointed barbs hooks any insect the woodpecker finds.

Birds Both Help and Harm Plants

Birds save the farmers of our country millions of dollars each year. They do this by destroying many of the insects which harm plants. Woodpeckers eat the insects that dig their way into the bark of trees. Swallows are birds that catch insects in the air. Many of the songbirds live mostly on insects.

In the spring, you can see birds bringing insects to the young birds in their nests. They make many trips all day long, carrying one or more insects on every trip.

If birds did not eat so many insects, there might be too many for the farmer to fight. Some insects lay so many eggs at one time that it is hard for us to imagine what would happen if all of them grew.

Although birds help in the battle against insects, they do not always fight on the side of the farmer. Sometimes birds dig up some of the farmer's seeds before the seeds have a chance to start growing. Some birds eat young plants in the spring before there are enough insects to eat.

We have to protect our gardens from birds, but we do not have to kill the birds to do this. Can you think of ways to protect a garden from birds?

Using What You Have Learned

1. You can collect insects with a homemade net made from a piece of wire, a broomstick, and some cheesecloth or curtain goods. Use your net to collect the kinds of insects you would like to watch.

   Once you catch the insects, you will need a place to keep them. You may want to use an insect cage. An easy way to make a cage for small crawling insects is to make a screen around the top of a flowerpot filled with moist soil. Use wire screening rolled up and fastened together. Be sure that there are no openings. Cover the top with cheesecloth or curtain goods. Keep grass or small plants growing in the moist soil.

2. Grasshoppers destroy many useful plants. Find out about their life history. When is the best time to destroy them? What would be a good way to get rid of them? These books may help you to do your report:

   The Grasshopper Book by Wilfrid S. Bronson
   Grasshoppers and Crickets by Dorothy Childs Hogner

With a parent along to help, these children are collecting insects and other small animals. Animal and plant collecting is a good way to learn a great deal and to enjoy the great outdoors.

TEACHING SUGGESTIONS
(p. 89)

Background: The following material will provide answers to the *Using What You Have Learned* section.

1. A large mayonnaise or pickle jar from your cafeteria, covered with gauze from the nurse's office, would also serve to catch insects. Place a twig or two in the jar, in addition to some leaves and moist soil or a wad of grass.

2. *Life of a grasshopper:* There are about 8,000 species of grasshoppers in the world, more than 600 of which are found in the United States. Grass is their most important food, but the grasshopper will devour any type of vegetation if grass is scarce. It is this that makes him such a nuisance to farmers.

The eggs of the grasshopper are laid in the ground in groups of 30 to 50. This occurs in the fall. The next spring a nymph, or miniature grasshopper, emerges with a large head, small body, and no wings. It sheds its skin as it grows, on the average of once a week. After five molts the grasshopper is a fully developed adult capable of reproduction. This growth pattern is known as incomplete metamorphosis.

TEACHING SUGGESTIONS
(pp. 90–92)

● **LESSON:** Are all soils alike in their abilities to support plant life?

Background: The five major factors in soil formation are climate, living organisms, parent rocks, topography, and time. These determine the weathering of rocks.

Soil is related to the earth somewhat like the rind of an orange, though it is far less uniform. It is deep in some places and shallow in others. It may be red, like many soils in Hawaii, or it may be black, like soils in North Dakota. Soils can be defined, classified, and mapped. Soil maps by the Department of Agriculture are used for a system of land classification which, in turn, leads to planting crops on the soil best suited for their ideal growth.

Learnings to Be Developed: Soils differ in their ability to support growing plants.

Developing the Lesson: Have the children bring in samples of the soils mentioned on pages 90–91: sandy, clay, and humus. Have additional soil samples collected from vegetable or flower gardens, from under trees in woods, from open fields, and from farm land. Let the children examine and handle

Green Plants—How to Grow Them

You have learned how green plants grow and how they are protected from weather, diseases, and animals. Now let's use what we have learned to start a vegetable garden. You will need to find out what kinds of vegetables will grow best in your garden. Some vegetables grow best where the summers are long and warm. Some vegetables grow better in one kind of soil than in another. How can you find out where different vegetables will grow best?

The Kind of Soil You Will Need

Every package of seeds tells you what kind of soil is needed for the seeds to grow well. Most soils are made up of very small pieces of rock. Such pieces of rock in soil are so small that you cannot see them easily. Other soils have larger pieces of rock in them. Look at some soil with a magnifying glass. Do you see small pieces of rock? There are other things in soil too. Do you know what they are?

Soil is made up of many materials. Examine soil from many places. How can you learn what materials are found in the soil that you examine? What would be a good source?

Humus holds the water, the sand begins to settle to the bottom. The appearance of the paper will depend on the activity of soil microorganisms. There undoubtedly will be colonies of various molds and bacteria present. If buried in moist woods, portions of the paper would be completely decomposed.

Can you explain what is happening in this picture? Which soil is sandy and which has humus in it?

Filter papers can be inserted in the ground in a number of locations around the school grounds, under a variety of vegetational covers. A tour to examine the papers makes an interesting field trip.

Some soils have a great deal of sand in them. Others have a great deal of clay in them. You can feel the difference between clay soil and sandy soil. Sandy soil feels rough when you rub it between your fingers. When clay soil is dry, it feels smooth, almost like a powder.

Clay and sand are also different when they are wet. Clay forms a sticky lump. When it dries, it gets very hard. Sand does not hold the water. The layer of sandy soil dries very quickly.

Sand, clay, and humus together make up **loam.** Most of our good soil is loam. It is darker than sand or clay. It does not stick together like clay. It holds water for plants better than sand does. **Humus** (YOO-muss) is formed from plant and animal material that decays. When plants die, their roots decay. Their leaves and stems become mixed with the soil, and then decay. The remains of decayed plants form humus.

Humus adds minerals to the soil. It helps the soil to hold more water and keeps it from becoming dry and hard. Humus also increases the amount of air space in the soil. Why is this important? Mixing manure or decayed leaves with soil is a good way to add humus to it.

You can measure the amount of water that different soils will hold.

the different types of soil. Discuss differences of color, texture, amount of moisture, etc.

Children may find it interesting to study the rate of humus formation. The rate of decomposition of organic matter to form humus can be determined by placing pieces of filter paper in the soil. Filter paper, like dead vegetation, is largely cellulose.

For this activity, insert a spade or garden trowel about 6 inches into the ground vertically, and open a slit by pushing the handle of the tool several inches forward. Remove the tool from the ground, and insert a piece of filter paper, folded once, so that about an inch remains above the surface of the ground.

Remove the filter paper from the ground at the end of two or three weeks, being careful not to tear it. This is best done by lifting out the soil containing the paper with a shovel or trowel. Examine the paper for evidences of decomposition.

ADDITIONAL ACTIVITIES:

Make a soil profile. With a spade, make a vertical cut about 3 feet deep into a sloping area, such as a steep roadbank or hillside. You will notice several distinct layers of soil.

The top layer will be rather dark colored. It contains organic material mixed with mineral matter. This is the topsoil. Soil scientists call it the "A layer."

Under the topsoil is the subsoil, or "B layer." The subsoil is usually a lighter, richer, brown color than the topsoil. Many soluble minerals and much of the fine silt from the topsoil are carried down to the subsoil by water seepage.

The "C layer" may not be reached in your cut. This is the unweathered parent rock material and may be many feet beneath the surface.

Compare the texture and compactness of the topsoil with the subsoil. Notice that root growth is much more abundant in the topsoil than in the subsoil.

Background: The following material will provide information for the *Questions to Think About* section.

The answers will vary according to the types of soil you investigated. In general, sandy soils will hold the least water, and soils rich in loam and humus, the most.

Seeds depend on moisture rather than nutrients for germination, so the soil that holds the most water would be best for planting seeds.

EXPERIMENT

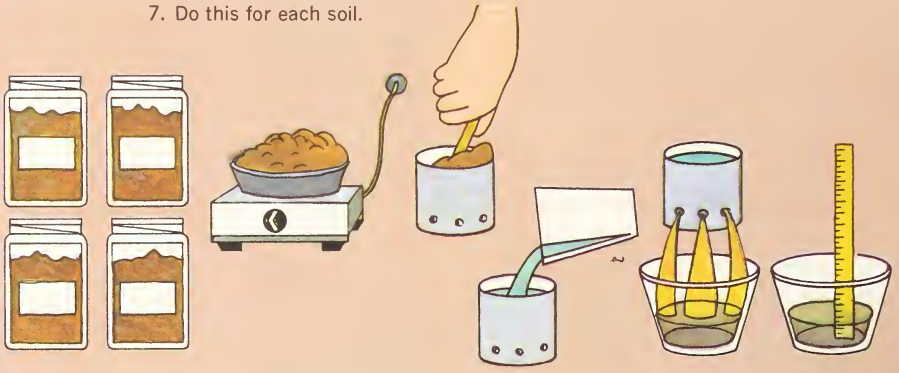
Do Different Soils Hold Different Amounts of Water?

What You Will Need

different kinds of soil
a few tin cans
pan
water
electric hot plate

How You Can Find Out

1. Collect several jars of soil from different places and label each jar.
2. Dry out each soil by heating it in a pan over a hot plate.
3. Punch small holes at the bottom of a can and fill it exactly half full with one of the soils.
4. Pack the soil down lightly.
5. Fill the can to the top with water.
6. Collect the water that runs through the holes at the bottom of the can. Measure the amount.
7. Do this for each soil.



Questions to Think About

1. Which soil let the most water go through?
2. Which one held the most water?
3. Which do you think is the best soil to plant your seeds in?

Starting Seeds

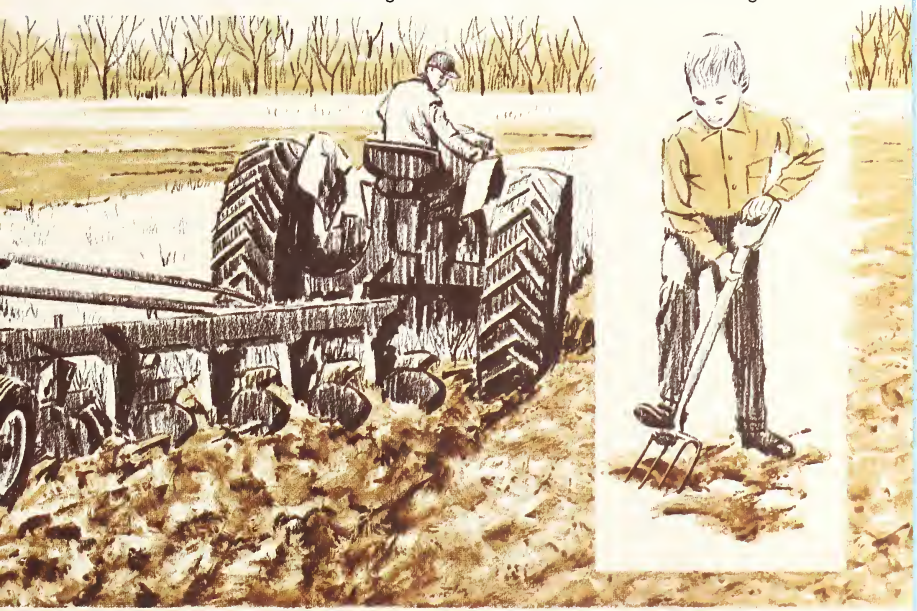
When seeds are planted, they must get air and water. The little plant inside the seed needs both to grow. If bean seeds in a glass are covered with water, they will not grow properly. That is why you were told on page 70 to use moist blotters to get the seeds started.

When you plant seeds, you must make sure that they will get enough air. Before planting the seeds, you should loosen the soil. In this way, more air can get into the soil.

Loosening the soil also helps the little plant in other ways. When the plant begins to grow, its stem and roots can push and spread through the soil more easily. It will be easier for water to get into the soil.

After the seed is planted, loose soil should be pressed around it. Particles of soil must touch the seed on all sides. Can you tell why this is important?

In these pictures, you see two ways to loosen soil. Can you tell why it is important that this task be done before seeding? What else needs to be done before seeding?



(pp. 93–95)

LESSON: What must man do to soil to insure good plant growth?

Background: In order to prosper, plant life must have continuous supplies of light, carbon dioxide, oxygen, water, and mineral salts. Where these are deficient, man attempts to supply them.

A seed contains the embryonic plant, and has a large supply of sugars and starches available for its first period of growth. When the seed produces the first green leaves, it is a seedling and no longer depends on stored food. It then needs all the nutrients required by larger plants.

Learnings to Be Developed: Minerals and water are needed by green plants in order to grow.

Developing the Lesson: Children can see for themselves just how necessary water and air are for proper plant growth. Place about 25 radish or cucumber seeds under water in a small dish, and cover with a blotter. Place the same number of the same kind of seeds between moistened blotters in another dish. Now place the same number of the same kind of seeds between dry blotters in a third dish. Examine the three dishes daily. It will soon become evi-

dent that only the seeds in the second dish, which had both water and air, will grow.

In doing this experiment, discuss the necessity for using a large number of seeds in each dish. Since some of the submerged seeds *may* germinate, and some of the moistened seeds *may not,* it is important to have a sufficient number of trials to allow for individual differences. If only one or two seeds are used in each dish, the total number of trials is small, and the experiment may yield misleading results.

ADDITIONAL ACTIVITIES:

Children may be interested in testing the importance of other factors for plant growth.

1. Select two small, well-established, green leafy plants. Place one in a warm, tall, well-ventilated box. Put the other in a convenient well-lighted place. Be sure to water both plants regularly. Note the stem length of both plants at the start of the experiment, then measure the stems after 5, 10, and 15 days. Make note of other differences as well, such as the number and texture of new leaves.

2. Plant radish seeds in a flat, earth-filled box, about 12 inches square. As soon as seedlings appear (about 8 days), cover one half

Adding Minerals to the Soil

Plants need minerals. They get their minerals from the soil. Each time vegetables are grown on a farm or in a garden, the vegetables take away some of the minerals from the soil. We get the minerals our bodies need when we eat plants.

After a while, the mineral supply in the soil becomes low. If it gets too low, plants will not grow well.

Before this happens, a good gardener or farmer adds minerals to his soil. He may use manure from animals or decayed leaves and plants. He may use chemical **fertilizers** (FER-til-yz-erz). Fertilizers are rich in important minerals needed by plants.

A gardener may have his soil tested for minerals before he plants his seed. He takes a little soil from his garden and sends it to the county agricultural agent. There the soil is tested by plant scientists. They tell him what kind of fertilizer he should put into his soil to make sure that his garden will grow well and will produce good crops.

A home gardener fertilizes his lawn after checking with his county agricultural agent.

An agricultural scientist checks soil samples. He can tell the condition of the soil.

Adding Water to the Soil

If a garden does not get enough rain, it has to be watered. It is not enough to sprinkle it lightly with a hose. Why is it important to see that the water gets down into the soil?

What time of day do you think would be best for watering your garden? Why is the middle of the day not a good time?

The picture at the right shows the kind of sprinkler you might find on a farm or a nursery. Home gardeners can attach sprinklers to garden hoses.

Sprinklers are a good way to water gardens and lawns without much effort.

Using What You Have Learned

1. Make a plan for a garden in your neighborhood. The answers to these questions will help you make your garden a success. Where would be a good place for one? What vegetables will grow well in your climate? How and when should the seeds be planted? Who will prepare the soil? Will it be necessary to water it? How will you water it? Will the soil have to be fertilized? How can you find out?
2. Some soil is not good for gardens because it has too much acid in it. You can find out if soil is acid. Mix water with the soil. Put a piece of blue litmus paper, which you can buy in a drugstore, halfway into the mixture. If the soil is acid, the water will turn the paper pink. Test soil from many different places to find out whether it is acid. Find out what you should do with acid soil.

of the box with black cloth to exclude light. The seedlings deprived of light will die, because they will use up the stored food of the seed and will be unable to make new food without light.

Background: The following material will provide information for the *Using What You Have Learned* section.

1. Answers and designs will vary. Seed packets from commercial seed houses indicate all essential information regarding the seeds. Moisture, soil, and light requirements are listed. There is also information regarding germination time and growing period for your section of the country.

2. A home gardener's soil-testing kit will be more reliable here if you can arrange for one. It is relatively inexpensive. Among the common plants which require acid soils are andromeda, azalea, blueberry, chrysanthemum, lily, magnolia, radish, and most evergreens. Acidity below a pH of 4 (7 is neutral) is too extreme for even the most acid-loving plants. Most such plants have a range of 4 to 6.5. Soil is brought back to normal, or toward alkalinity (pH 7 to 9), by the addition of lime. Sulfate of potash is used to make soil more acid.

TEACHING SUGGESTIONS
(pp. 96–97)

Background: These two pages constitute a review of the concepts and terminology introduced in this unit.

What You Have Learned: This is a summary of the entire unit, with new words in boldface type.

WHAT YOU KNOW ABOUT
Living Things—Green Plants

What You Have Learned

Green plants are the world's food makers. All animal life depends on green plants.

Chlorophyll gives green plants their color. Plants with chlorophyll use the light energy from sunlight to make food from water and **carbon dioxide.** This process is called **photosynthesis.** The food that green plants make is a sugar called **glucose.** Glucose is used by the plant to make other kinds of foods. Glucose and the foods made from it have the energy of sunlight stored in them.

Carbon dioxide needed by the green plant enters through tiny openings in the **leaves.** Water and minerals enter through the **roots. Stems** carry food and water to all parts of the plant.

Green plants store the food that they do not use in their roots, stems, or seeds so that the food can be used at another time.

Because man depends on green plants, he must make certain his crops are healthy. Plant scientists find ways to protect plants from weather, diseases, animals, and insects.

We must protect plants from many animals that destroy them. But we must also protect the many kinds of animals that are helpful to growing plants. Some birds eat harmful insects. Some insects, such as the bee, help flowers to make new plants. Some insects destroy harmful insects.

In order to grow healthy plants, we must plant them in good soil. Most of our good soil is **loam.** Sand, clay, and **humus** make up loam. Sometimes a farmer must use chemical **fertilizers** to add minerals to the soil.

Checklist of Science Words

Here are some science words you read about in this unit. Can you tell what you have learned about each one?

bulb	glucose	photosynthesis
chlorophyll	humus	roots
fertilizer	life history	stems
fungi	loam	weeds

Find the Answer

Write the numbers 1 to 6 in your notebook. Next to each number, write the word that best completes that sentence.

1. Carbon dioxide enters the plant through openings in the ___?___.
2. The part of the plant that spreads out into the soil is called the ___?___.
3. Food and water are carried up the ___?___.
4. The ___?___ take up water and minerals from soil.
5. The ___?___ supports the plant.
6. Glucose is made in the ___?___ of a green plant.

Complete the Sentence

Write the numbers 1 to 5 in your notebook. Next to each number, write the answer that best completes that sentence.

1. The green chemical that makes plants green is ___?___.
2. Green plants get energy from the ___?___ to make food.
3. The food that green plants make is ___?___.
4. A plant may store food in its ___?___, ___?___, and ___?___.
5. The best kind of soil to grow plants in is ___?___.

Checklist of Science Words: Remind the pupils that there is a *Dictionary of Science Words* on pages 318–325. They should consult this dictionary whenever they are unsure of the precise meaning of a word.

Find the Answer:

1. Leaf
2. Roots
3. Stem
4. Roots
5. Stem
6. Leaves

Complete the Sentence:

1. Chlorophyll
2. Sun
3. Glucose
4. Leaves, stem, and roots
5. Loam

TEACHING SUGGESTIONS
(pp. 98–99)

Background: These pages reinforce the concepts presented in the unit by suggesting activities that extend the pupil's ability to apply the learnings derived from the unit.

What Are the Words?

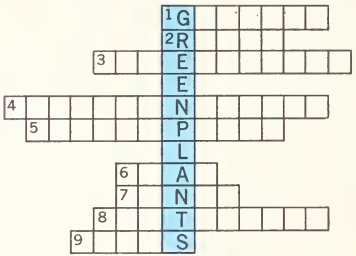
1. Glucose
2. Roots
3. Development
4. Photosynthesis
5. Chlorophyll
6. Loam
7. Fungi
8. Fertilizer
9. Humus

YOU CAN LEARN MORE ABOUT
Living Things—Green Plants

What Are the Words?

Write the words in your notebook.

1. Sugar that green plants make.
2. They get water from the soil.
3. How insects grow and change.
4. The putting together of carbon dioxide and water, in sunlight, to make sugar.
5. Green plants need this chemical to make food.
6. The best kind of soil.
7. Plants that cannot make their own food.
8. This is added to the soil to give it minerals.
9. Material formed from decayed plants and animals.



Can You Tell?

Mr. Burns will not get good crops this year because he has not taken good care of his fruits and vegetables. Look at the picture of Mr. Burns's farm and tell how many things you can find wrong.

You Can Make a Terrarium

You will need plants of different sizes, stones or pebbles, twigs and bark, nuts, pine cones, charcoal, and soil.

Put about an inch of soil in the bottom of the tank and wet it a little. Next, put the larger plants into the tank. Then put in the smaller plants. Finally, arrange the rest of the things in the tank. Sprinkle it with water. You should keep the soil damp, but never wet. Use pieces of charcoal in your terrarium to remove odors. To finish, put a piece of glass across the top of the tank.

You Can Read

1. *The First Book of Plants* by Alice Dickinson. You will learn how plants make food, grow, and reproduce.
2. *All About the Flowering World* by Ferdinand C. Lane. Descriptions of many unusual plants.
3. *Plants in the City* by Herman and Nina Schneider. Tells about plants that grow in the city.
4. *The Wonderland of Plants* by Terry Shannon. Tells the life stories of many different plants.
5. *Play with Plants* by Millicent E. Selsam. How to do simple experiments to learn about plants.

You Can Read: Here is some additional reading for the teacher and the pupils.

Trees and Trails, by Clarence John Hylander (Macmillan, 1953).

The Wonders of Seeds, by Alfred Stefferud (Harcourt, 1952).

What's Inside of Plants?, by Herbert S. Zim (Morrow, 1952).

Plants: A Guide to Plant Hobbies, by Herbert S. Zim (Harcourt, 1947).

Films:

Arctic Borderland In Winter (11 min., b/w & color, Coronet). Shows how living things adapt to unusually difficult living conditions.

Leaves (11 min., b/w, Encyclopaedia Britannica Films). Describes the structure, function, and types of leaves. Shows in detail the parts of a leaf and illustrates the arrangement of cells and veins in the process of making food.

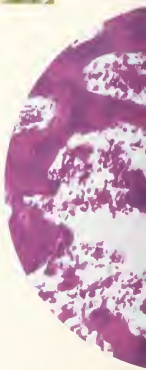
Roots of Plants (11 min., b/w, Encyclopaedia Britannica Films). Shows various kinds of roots. Describes structure, processes of growth, food and water intake, and sensitivity. The function of root hairs is explained.

Key Concept 1. Events in the natural environment happen in an orderly rather than a haphazard way; man searches for laws to explain this order by observing, hypothesizing, checking his ideas, and rejecting those which do not square with reality.

Key Concept 3. To find order in the natural environment, the scientist seeks basic units that can be put together in an almost infinite variety of ways; the cell and the atom are examples of such units.

Key Concept 7. When equilibrium is upset in organism-environment interactions, regulatory mechanisms go to work to restore equilibrium.

Key Concept 8. There is a relationship between structure and function; the structure of parts of living organisms determines the function of those parts.



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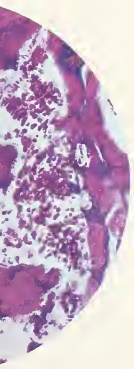
Other concepts appear under "Learnings to Be Developed" in each lesson found in the Teaching Suggestions.



Animals–Simple and Complex

Being Alive

Animals—A Closer Look

Animals—How They Are Grouped

CONCEPTS:

1. To keep alive, all living things must carry on certain life activities.
2. All living things are made up of cells.
3. There are ways of distinguishing between plants and animals.
4. The kinds of animals range from very simple to highly complex ones.
5. Animals are adapted to the environments in which they live.
6. The classification of animals is based upon comparative structure.

PROCESSES:

- Observing—Pages 106, 107, 108, 110, 111, 112, 114, 118, 119, 121, 124, 125, 126.
- Comparing—106, 110, 111, 114, 115, 121, 124, 125, 133, 134.
- Classifying—102, 106, 113, 122, 123, 124, 125.
- Selecting (sources from recall)—109, 115, 116, 119, 121, 131.
- Communicating—113, 115, 130, 131, 132, 133, 134, 135.
- Demonstrating—126.

Look at the pictures. Can you pick out the things that are alive? Look again at the pictures. What are the differences between something that is alive and something that is not alive? You will find out in this unit. When you find out, you will know what it means to be alive.

Being Alive

What do you need to stay alive? How might you find the answer to this question? One way might be to find out what things plants and animals need to stay alive.

Do Living Things Need Oxygen?

Do plants need air? Does a horse need air? Do you need air? Do rocks need air? Plants take in air all the time. Horses breathe all the time. So do you. Do rocks breathe?

Living things need **oxygen** to stay alive. Oxygen is a gas that is found in the air. Plants and animals need oxygen to live. They get their oxygen from the air around them. You learned that green plants need carbon dioxide for photosynthesis, but they also need oxygen in order to live. Plants and most animals that live in the water have a way of getting their oxygen from the air that is in the water. *All living things need oxygen to stay alive.*

How many living things do you see?

(pp. 102–105)

LESSON: What does it mean to be alive?

Background: From earliest times it was believed that living things can originate from nonliving material. Known as the doctrine of spontaneous generation, this was the view of the classical philosophers —Aristotle, Lucretius, and others who influenced Western thinking for 2,000 years. It was the generally accepted view all through the Middle Ages and well into the 17th century.

The following quotation from the works of the Flemish physician and chemist Jan Van Helmont, who lived from 1577 to 1644, is typical:

"Furthermore, if a dirty undergarment is squeezed into the mouth of a vessel containing wheat, within a few (say 21) days the ferment drained from the garments and transformed by the smell of the grain encrusts the wheat itself with its own skin and turns it into mice. . . . And what is more remarkable, the mice are neither weanlings, nor sucklings, nor premature; but they jump out fully formed."

WHICH ARE ALIVE?

How can you tell which things in each picture are living?

It is important to point out to your pupils that Van Helmont was not making this up; he actually carried out an experiment, and this is the way he reported his results. Two hundred years later Pasteur commented on this quotation: "What this proves," he said, "is that to do experiments is easy; but to do them well is not easy."

There were scientists who did not believe in spontaneous generation. Francesco Redi was one such scientist.

For a long time, it was believed that worms came from rotting meat. Francesco Redi believed worms somehow came from other living things. He used gauze to cover a jar containing a piece of meat.

As the meat began to rot, flies were attracted to it by its odor. The flies laid their eggs on the gauze. Later, worms appeared on the gauze. They had hatched from the eggs. They were not true worms but maggots which later changed into flies. Redi had shown that the worms were not made from the meat at all. Thus Redi showed us experimentally that living things come only from other living things.

Learnings to Be Developed:

To keep alive, all living things must carry on certain life activities.

These life activities include getting and using oxygen and food, removing wastes, and producing offspring.

Developing the Lesson: Begin with a discussion of the things children need to stay alive. Stress the fact that all animals have the same basic needs as children do.

You can demonstrate the need for oxygen, using a goldfish. Prepare two jars, one containing water which has been allowed to accumulate air bubbles by standing for several hours, and another containing water which has been freshly boiled and allowed to cool to room temperature. With a dip net, place a healthy goldfish in the second jar. As soon as the fish appears at the surface to gulp air, remove it to the first jar. Have pupils note the difference in the behavior of the fish in the two jars. Direct their attention to the gills of the fish. The rate of opening and closing is a key to its breathing or respiration rate. Since boiling removes much dissolved air from water, the contents of the second jar will be deficient in

Do Living Things Need Food?

Food is used for energy and for growth. The food that living things eat supplies them with stored chemical energy. You learned about this when you learned about green plants.

A plant does not get its food in the same way as a horse or a bird or a person. A plant gets materials from the air, from the soil, and from water. The plant uses these materials to make its own food. Animals get their food from green plants or other animals that have eaten green plants. *All living things need food to stay alive.*

Do Living Things Need to Get Rid of Wastes?

When living things use oxygen and food, they form wastes in their bodies. These wastes must be removed, or they will poison the living things.

Your lungs, your skin, and your kidneys help remove the wastes from your body.

All animals and plants must get rid of their wastes. Even tiny plants and animals, so small that they can be seen only with a microscope, must get rid of their wastes. *All living things must get rid of wastes to stay alive.*

Do Living Things Produce Other Living Things?

Look again at the pictures on pages 102 and 103. Where do new plants come from? Where do new birds come from? Now look at the automobile. Where do new automobiles come from?

Plants can produce more plants. Birds can produce more birds. Horses can produce more horses, and people can produce more people. But an automobile *cannot* produce another automobile. *Only living things can produce other living things like themselves.*

"What does it mean to be alive?" Let's review. All living things need oxygen. All living things need food. All living things must get rid of wastes. Living things can produce more living things like themselves.

The Life Activities of Living Things

To stay alive, all living things must carry on certain **life activities.** You have just learned about some important life activities—using oxygen, using food, and getting rid of wastes. Producing more living things is also a life activity. But it is different from other life activities.

If a living thing does not have oxygen, does not have food, or does not get rid of wastes, it will die. A living thing will not die just because it does not produce more living things like itself.

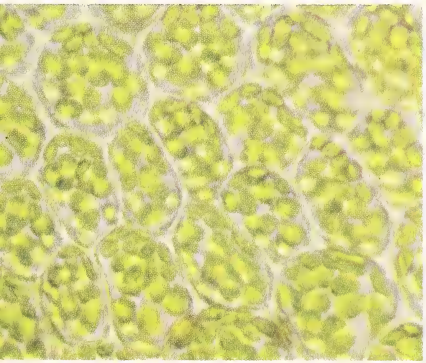
But what would happen if all living things did not produce more living things like themselves? What would take the place of the living things that died, or were eaten by other living things, or were destroyed by enemies?

All the life activities of living things —using oxygen, using food, getting rid of wastes, producing more living things like themselves—use energy. Where does this energy come from? The energy is given off by the burning of food within the living things. The food for animals comes from green plants or from animals that have eaten green plants. Green plants, as you already know, make their own food by using energy from the sun.

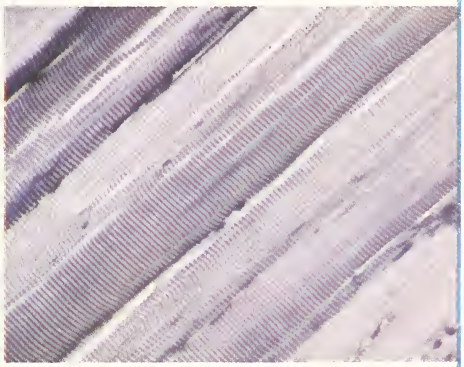
All Living Things Are Made of Cells

You have learned that plants and animals are living things. This means that they are alike in some important ways. You have already learned that both plants and animals carry on life activities. Another way in which they are alike is that both plants and animals are made up of **cells.** A cell is a tiny unit of living material.

These cells are from a green plant. What do you see inside each plant cell?



These are muscle cells from a human body. Where do you think you have such cells?



oxygen, and the breathing rate of the fish will be faster.

Follow-Up: Build a small aquarium as a class project. Discuss the need for supplying food, air, and proper temperature to keep the fish alive. Talk about how wastes will be taken care of. Let children understand the need for plants as oxygenators and to provide food for the fish, and the need for a few snails to remove wastes. Perhaps you will place a male and a female of the same species in the tank, allowing for reproduction. Discuss the idea of a balanced aquarium, where there is an interdependence between animal and plant life. Have children recall that plants use the carbon dioxide given off by animals to produce the food which the animals will eat. Remind them also that plants give off the oxygen needed by animals for respiration. Help pupils see that the balance between the needs and the supply of plants and animals is the mark of a successful living community.

○ ADDITIONAL ACTIVITIES

Have pupils list the foods eaten by common animals: pets and farm creatures, insects, wild forest animals, sea animals, etc. Discuss these foods in relation to the environment of each animal.

TEACHING SUGGESTIONS
(pp. 106–107)

LESSON: What structures do all living things possess?

Background: The text for this lesson begins on page 105.

We are concerned here with levels of organization in living things. The primary level of organization is atomic and molecular in nature, but the text does not deal with this. If you have an advanced group of pupils, you may feel that the class can understand the concept and it might be profitably introduced at this point.

The second level of organization, the cellular, is the main topic of this lesson. With minor exceptions (viruses), all living things contain cells. The cell is a geometric volume and may take a variety of shapes. It is worthwhile recalling here that all living cells utilize oxygen in order to produce energy; all cells eliminate cellular wastes; all cells grow; most cells reproduce. Many cells are organized with their neighbors to form a system for carrying out special functions more efficiently.

There are many kinds of cells. Compare the pictures on these pages. How are these cells alike? Remember that the pictures you see are hundreds of times larger than the real cells. How do you think scientists are able to see real cells if the cells are so small?

Think of cells as building blocks. If you were making houses out of blocks, you could make the houses any shape or size that you wanted. You could do this by using more or fewer blocks, or by arranging the blocks in different ways. No matter what the shape or the size of the houses you made, all the houses would be made out of these blocks. This is also true for all living things. No matter what the shape or size of a living thing, it is always made out of cells. The cell is the building block of all living things.

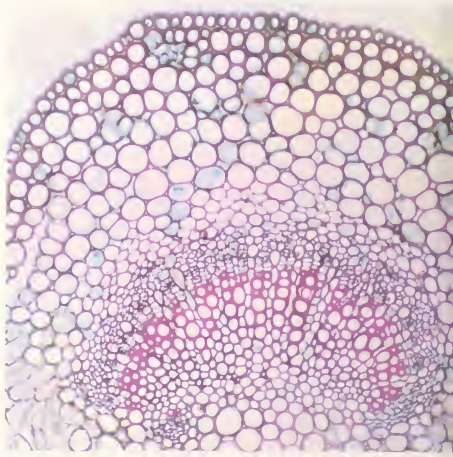
Some plants and animals are only one cell, but others are made up of millions of cells. You will be learning more about cells as you learn more about living things.

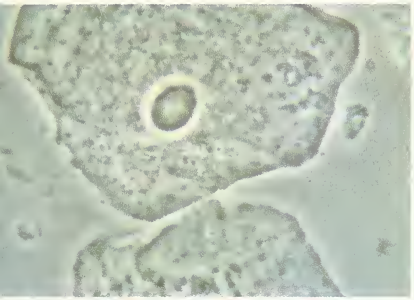
How Plants and Animals Differ

Look again at the pictures of the plant and animal cells. Compare them. Do you see any difference between the plant and animal cells? Notice the thick, firm wall around the plant cells. Do you see any such wall around the animal cells?

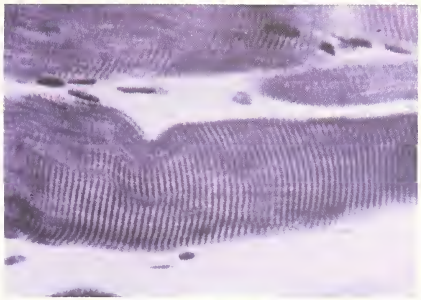
There are other important differences between plants and animals. Green plants, as you already know, make their own food. Do you remember how they do this? Animals cannot make their own food. The animals that you know move about from place to place. The plants that you have seen growing must stay in one place.

Some of the cells you see in this picture carry food and water to parts of the plant.





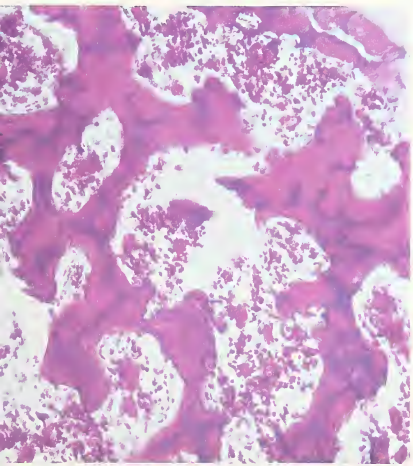
Cheek-lining tissue



Muscle tissue

PLANT AND ANIMAL CELLS

Connective tissue



What differences do you see among the cells? Can you tell which are plant cells and which are animal cells? How do you know?

Could a scientist see root cells by looking at a root? How do you think he studies the cells shown?

Learnings to Be Developed:

All living things are made up of cells.

Cells vary in their appearances and their functions.

Developing the Lesson: Introduce the work of this lesson by recalling the lessons on cells in the previous unit on plants. If a microscope is available, set up some demonstrations of cell types. Prepare slides of onion and cheek cells, and prepare a slide of elodea, a green water plant. If possible, use a bioscope or microprojector so that the whole class can observe and discuss the cells. You can make your own slides for this activity; directions for doing so are given in most high school biology textbooks. Or, you can obtain prepared slides from biological supply houses. National Teaching Aids, Garden City Park, New York, has inexpensive sets of microviewers and slides that are ideal for showing cellular structure. Samples are available on request.

TEACHING SUGGESTIONS
(pp. 108–109)

● **LESSON:** How do plants and animals differ?

Background: The differences between animal and plant life can be briefly stated as follows: On the cellular level, both contain cell membranes, nucleus, and cytoplasm. However, only plant cells have cellulose walls, large sacs or vacuoles containing water and wastes, and chloroplasts for the manufacture of chlorophyll. Plants have only limited motion, while animals can move about with varying degrees of freedom. Plants can manufacture their own basic food, but animals cannot.

Learnings to Be Developed: There are ways of distinguishing between plants and animals.

Developing the Lesson: Have the children go back to the pictures on page 107. Identify the plant cells in the stem and the onion root. Identify the muscle cells and other animal cells.

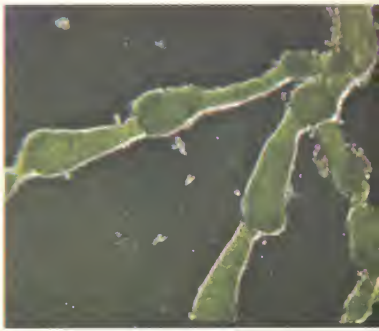
- *What do you notice about the plant cells that is different from the animal cells?*

Pupils should be able to see that there is a more structured and regular geometry to the plant cells. The cell endings are easily

Pitcher plant

Venus flytrap

Bladder wrack



Algae

WHAT ARE THEY?

Can you identify the living things on this page? What can you find out about each one? How will you go about finding out about them?

Sea anemone

Did you know that there are plants that cannot make their own food? There are also plants that can move and animals that seem to stay in one spot. So you see, even though plants and animals are different in many ways, it is not always easy to tell them apart. In some cases, it is very hard even for a scientist to say which is a plant and which is an animal.

Is It Plant or Animal?

You are going to make a **survey.** A survey is a way to get information. Scientists make surveys. When scientists make a survey, they try to get information. They keep a written record of what they find.

You can make a survey of some living things. You can make a survey of how many kinds of living things can be found where you live.

When you make your survey, you may want to make a chart like the one below. It will help you keep a record of the plants and animals you find.

Name of Living Thing or What Living Thing Looks Like	Where Seen	Date Seen

Any time is a good time to look for and study plants and animals.

Where will you look for plants? Where will you look for animals? Look everywhere. Look on the ground and in the ground, on trees and in trees, in the air, on the walls outside your house and in your house, on ponds, and on lakes.

Before you begin your survey, there is one very important question you must be able to answer. Can you tell which living things are plants and which are animals? Let's see. On the next two pages you will see some pictures of living things. Compare the pictures. Then make a record in your notebook. Write the names of the plants in one column and the names of the animals in another column.

discerned, and are almost regular in shape. Plant cells have a definite cell wall (cellulose). Animal tissues, on the other hand, generally have cells that are much smaller and less regular in shape. It is almost impossible to see the boundaries of muscle cells. The animal cells have only a thin membrane around them.

What is always found in green leaf cells that is never found in animal cells? (Chlorophyll or chloroplasts.)

Now study the pictures on page 108. Have children answer the questions.

Children are usually fascinated by the Venus flytrap. This is an insectivorous plant found in a coastal area of the Carolinas. It exhibits a response to touch that is very rare in plants. If a disturbance, such as the arrival of an insect, occurs at the juncture of the two sections of the leaf, the leaf snaps closed, and digestive enzymes are secreted which kill the insect and extract nitrogen and carbohydrates from it. If no victim is captured, the leaf opens again after a few minutes.

The survey exercise on page 109 is very valuable. In doing it, emphasize the importance of keeping good records.

TEACHING SUGGESTIONS
(pp. 110–111)

Background: Answering the questions on these two pages will give your pupils experience in grouping plants and animals. It will enable them to review and reinforce what they already know about the differences between plants and animals.

Your pupils will probably think the hydra, shown on page 111, upper right-hand corner, is a plant. This will provide you with the opportunity of pointing out that scientists themselves are not always certain of their groupings and must go beyond observational techniques to find out.

Tell your pupils they can find out more about any living thing by observing it or, if this is not possible, by reading about it.

ADDITIONAL ACTIVITIES:

Have your pupils bring in many pictures of living things. Tack these pictures on a bulletin board. When you think you have a sufficient number of pictures, draw two columns on the chalkboard.

PLANTS OR ANIMALS?

Which are plants? Which are animals? In your notebook, write the names of the animals in one column, the names of the plants in another column. Tell why you grouped each living thing the way you did. Do you find that some living things are hard to group?

Label one column *Plants* and the other *Animals*. Send pupils to the bulletin board to remove a picture and then have them write the name of the living thing in the appropriate column on the chalkboard. Each time a pupil does this, have him tell why he placed the living thing in that particular group. If pupils have difficulty with any picture, have them investigate the living thing and find out for themselves what the living thing is. You might discuss with your pupils the ways in which to find out about living things:

- field work
- laboratory work
- professional books
- museums
- zoos
- botanical gardens
- university scientists
- government scientists

The least obvious of the living things on these pages are the ferns, upper left-hand corner of page 110. Moss is shown in the second picture from the bottom on the left side of page 110. The hydra is on page 111, upper right-hand corner.

(pp. 112–113)

LESSON: Are there any organisms (living things) which are both plant and animal?

Background: The two organisms in this lesson are considered autotrophs—organisms that produce their own food. This, we know, is a characteristic of plants. However, their motility, and certain chemical factors, also give them some animal characteristics. The euglena is a flagellated organism with no cell wall. Both organisms have chloroplasts, and they store a starch only slightly different from that of higher plants. It has been found that, under certain experimental conditions, they can lose their chlorophyll. When this happens, they become heterotrophs, and live as other protozoans do, by taking food from their environment.

Learnings to Be Developed: Some organisms puzzle man in his attempts to label them plant or animal.

Now look at these two pictures of living things.

The pictures show how these two tiny animals look when we see them under a microscope. The **euglena** (yoo-GLEE-nuh) is often found in ponds. Sometimes there are so many of them that the top of the pond looks green. The euglena makes its own food, as do green plants. It has chlorophyll within its body, and it can carry on photosynthesis. However, it can swim like some animals.

The **chrysamoeba** (KRISS-uh-mee-buh) also depends on photosynthesis for food. However, there are times when it moves about and feeds, as do some animals.

You now know why scientists sometimes find it difficult to know which living things are plants and which are animals. Whenever scientists find a new living thing, they must compare it to the living things they know about. How does this help them to find out what it is?

On the left is a euglena. On the right are two views of a chrysamoeba. The top view shows it moving about and feeding as an animal does. The bottom view shows it when it is dependent on the process of photosynthesis.

Using What You Have Learned

1. Take a piece of paper and divide it into two columns. At the top of one column, write "Things That Are Alive." At the top of the other column, write "Things That Are Not Alive." Now look at the list below. Put the name of each object in the correct column. How do you know which things are living and which things are not?

elephant	pencil	book
rock	tree	fish
ant	automobile	grass
train	rosebush	puppy

2. Write a report on one of these animals: horse, spider, eagle, or seal. Tell how it carries on its life activities.

Developing the Lesson: Obtain a culture of euglena from a scientific supply house or from a local pond. Science supply houses charge about $3.00 for a supply of pure culture for about 25 children. Wards of Rochester or California is a reliable source. See the list of supply houses in the Teachers' Guide for the address. Examine the characteristics of the euglena. Observe its locomotion, its chloroplasts, and the eyespot, and discuss its classification as sometimes animal and sometimes plant. Encourage children to hypothesize about these organisms.

Animals—A Closer Look

As you compared living things, you found out in what ways they were alike and in what ways they were different. To compare one kind of living thing with another kind, you must study both kinds carefully. First you have to decide what things to observe. Then you have to decide how to observe them.

Suppose that you want to compare the sizes of two animals. Will it be enough to take a look at them and say that one is big and the other is small? What will you have to do? Suppose that you want to compare the way two animals move. Will it be enough to watch them and say that one swims and that the other runs? What will you have to look for?

Before you make a comparison, it will help you to make a list of the things you want to observe.

TEACHING SUGGESTIONS
(pp. 114–115)

LESSON: What does a scientist look for when making comparisons between animals?

Background: In spite of the many differences among species, certain forms of animal life possess homologous structures (arms, wings, backbones, etc.) that are either modified or absent in other forms. By grouping together the animals that have certain homologous features in common, we can classify several million forms into a relatively small number of groups. Such groups are called phyla. Within the phyla, we can examine other sets of homologous characteristics and further subdivide into class. By further progression in this manner, we can place all animal life in a system of classification based on their similarities and differences. For example, the common system of taxonomy or classification for the honeybee would be:

Kingdom—Animalia
Phylum—Arthropoda (jointed legs)
Class—Insecta
Order—Hymenoptera
Family—Apidae
Genus—Apis
Species—Mellifera

Comparing Two Animals

Let's compare an earthworm with an insect. Perhaps your class can collect enough earthworms and insects so that everyone will have one of each to observe.

If it is not too cold, you can find earthworms and insects such as ants, ladybugs, or butterflies in many different places. A good place to look for earthworms and ants is underneath rocks or boards that have been left on the ground.

If you cannot collect earthworms and insects, use these pictures to help you with your comparison.

As you observe the two animals, try to answer these questions:

How are their shapes different?
How long is each one?
Which one has legs? How many?

If you have live earthworms and insects, answer these questions:

How does the earthworm move?
Which has the softer body?

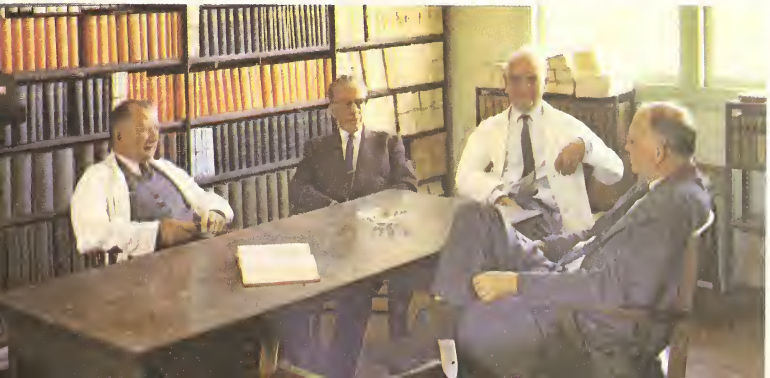
Here are some other questions you might not answer so easily. You would have to observe both animals for a long time to find the answers:

What does each one eat?
Where does each one spend the winter?
How does each one produce other animals like itself?

A good way to observe earthworms and ants is with a magnifying glass. What would you have to do if you wanted to see these animals under a microscope?

But there is another way you could find the answers to these questions. You could read what scientists who study living things have written about these animals. Such scientists are called **biologists** (by-OL-uh-jists), and **biology** (by-OL-uh-jee) is the study of living things. When a biologist studies an animal, he observes it for a long time. He keeps a carefully written record of what he finds out. He compares his record with the records of other biologists, to make sure that his observations are correct.

The information that biologists have gained through observation is printed in books. How would you find books about earthworms and insects?



Biologists use many instruments, study other scientists' records, and discuss their findings.

Learnings to Be Developed: By observing animals and studying their structures, we can learn about the groups to which they belong.

Developing the Lesson: Discuss each question to be sure children fully understand what they are looking for. In comparing shapes, for example, pupils should look for symmetry and its types—bilateral and radical. In looking at the animals' legs, children should observe not only the number but also places of attachment. They should compare the joints with human joints, looking for similarities and differences. In comparing insects, point out to the children that a knowledge of life histories may be important, since some insects go through stages that are totally dissimilar to their adult form. Throughout this activity, remind children to keep accurate records of their observations.

ADDITIONAL ACTIVITIES

Have pupils survey the animals seen in their neighborhoods. They may include pet dogs, cats, fish, birds, turtles, etc. The survey should include observations on how these different animals breathe, eat, reproduce, move, get rid of wastes, and are sensitive to stimuli.

TEACHING SUGGESTIONS
(pp. 116–117)

LESSON: What is the simplest form of life?

Background: It is often quite difficult to place a given organism in the plant or animal category. Our study of the euglena and chrysamoeba showed this difficulty very clearly, as does an examination of bacteria, yeast, and molds, which are classified as plants though they do not contain chlorophyll. As a solution to this problem, an increasing number of biologists are favoring a three-kingdom organization of life, dividing all organisms into plants, animals, and protists.

The protists include euglena, bacteria, ameba, paramecia, slime molds, yeast, and other indistinct forms of life which have puzzled taxonomists for years. Fungi and mushrooms are in this group also, as well as most of the organisms once called protozoa.

In this lesson, the ameba is studied as a simple type of animal.

Learnings to Be Developed:

Some animals have only one cell.

The one-celled ameba carries on all the basic life functions.

Developing the Lesson: You could begin by showing portions of the

Animals—Simple and Complicated

When a biologist compares animals, he finds that some are **simple** and some are **complicated**. A simple animal has few parts. A complicated animal has many different parts. It is like comparing machines. Suppose that one machine has only two parts and another has twenty parts. Which would you say is simpler? Which would you say is more complicated? In the same way, an animal with only a few parts is simpler than an animal with many parts.

You are now going to make a careful comparison of three animals. As you study these animals, try to find out how they are alike and how they are different. You should also try to find out how each animal carries on its life activities.

As you compare, remember that the scientist uses the word *animal* in a way that may be different from your use of the word. You have probably used the word *animal* for such living things as horses, cows, dogs, monkeys, lions, and cats. Some boys and girls think that only living things that walk on four legs are animals. But when a scientist talks about animals, he means *all living things that are not plants*. Be sure you know the difference.

A duck is an animal. So is an earthworm. So is a ladybug. Can you name other living things that boys and girls don't usually think of as animals?

To help you know if something is an animal, ask yourself these questions:

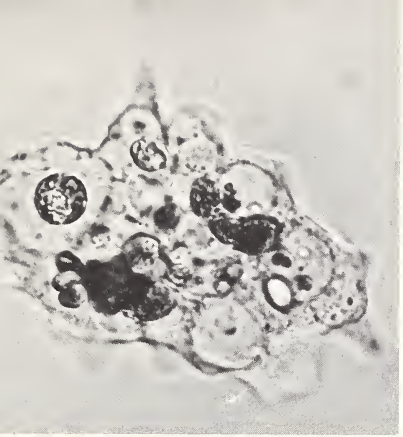
Is it alive?
Does it move about?
Does it depend on green plants for food?

It is not always easy to tell if a living thing is a plant or an animal. But the questions above will help you to tell which is which.

A One-Celled Animal

The simplest animals are those that have only one cell. An **ameba** (uh-MEE-buh) is a one-celled animal. It can only be seen through a microscope. An ameba looks like a very, very small piece of live gray jelly with a dark spot inside it.

What things do you think the ameba needs in order to live? What things do you think the ameba can do?



Above you see an ameba, and to the right you see it feeding. Can you describe how it feeds?

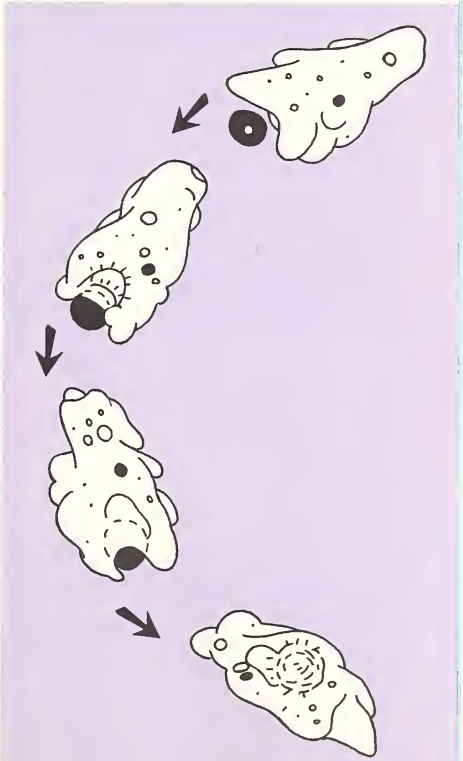
The ameba cannot live outside of water. It gets its food and oxygen from the water. Food, oxygen, and water pass through a thin covering which is the outside of the ameba's body.

Waste materials pass out through the ameba's thin covering. This covering is very special. It lets only certain things in and out.

The ameba catches its food by wrapping itself around the food. Look at the picture to see how it does this. The food then passes into the inside of the ameba, where the ameba can make use of it. From what you know about living things, can you tell what use the ameba makes of food?

The ameba, which is only one cell, can take in oxygen, eat, get rid of wastes, and produce more amebas.

The ameba moves about. It has been seen to move as much as one inch per hour—a long trip for this tiny animal.



film, *Life in A Drop of Water*, if it is available. Following, or in place of, the film, mount a drop of pond water on a clean glass slide and show it to the class on a microprojector, under the low power. Pupils will be delighted, and probably surprised, to observe the numerous forms of life found in a single drop of such water.

One of the commonest forms they will observe is the paramecium, a cigar-shaped animal which moves rapidly by means of tiny, hair-like cilia. Point out that it is a one-celled animal which carries on all the necessary life activities. It may be observed sweeping tiny food particles into its mouth and gullet by means of the cilia. It reproduces by splitting into two, equal-sized "daughter cells."

The ameba, described in the text, is another one-celled animal. This animal changes shape continually. It moves by extending its false feet, or pseudopods, which it also uses to engulf the tiny plants which serve as its food.

Also like the paramecium, the ameba reproduces by a method known as fission. When it reaches a certain size, it divides into two daughter cells, which in turn grow and divide in two.

TEACHING SUGGESTIONS
(pp. 118–121)

LESSON: How are many cells organized in an animal?

Background: The hydra belongs to a group of hollow-bodied animals known as coelenterates. Other members of this group are jellyfishes and corals. These possess two layers of cells, between which is a jelly layer containing scattered cells. The tentacles contain stinging cells, capable of discharging a tube armed with barbs and loaded with poison to immobilize prey.

The hydra has special sensory cells scattered through its body, which receive and transmit messages to a network of nerves that runs through the whole body.

The cells of the hydra absorb oxygen dissolved in the water directly through their cell membranes. They excrete liquid and gaseous wastes in the same way. The hydra reproduces in two ways. It may either from a bud which later becomes detached from the parent, or it may reproduce by sperm and egg cells.

Learnings to Be Developed:

Animal types range from very simple to very complex.

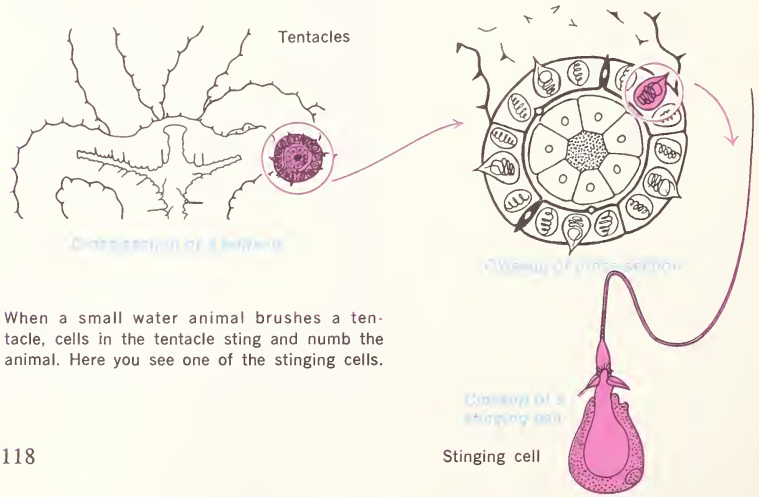
A Simple Many-Celled Animal

Attached to the rock in the picture is a little animal called a **hydra** (HY-druh). The hydra's stringy arms are called **tentacles** (TEN-tuh-kulz). Hydras, which are about half an inch long, are found in streams and in ponds. The hydra, like the ameba, gets the oxygen it needs from the water. But, as you will see, a hydra is a more complicated animal than an ameba.

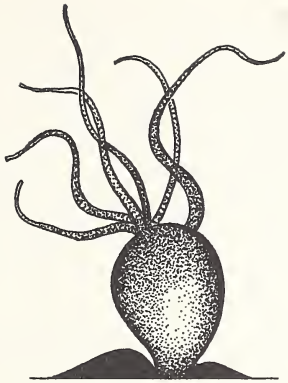
To examine a hydra you would need a microscope. A hydra's body is made up of two layers of cells. The drawing shows how they are arranged. The cells in the outside layer protect the cells in the inside layer.

The hydra's body gives off a sticky material, which it uses to "glue" itself to water plants.

Some of the outside cells can shoot out poisonous threads that numb the smaller animals on which the hydra



When a small water animal brushes a tentacle, cells in the tentacle sting and numb the animal. Here you see one of the stinging cells.



When danger threatens, the hydra draws itself into a small knob. How does this protect it?

feeds. The tentacles then pull the food into the hydra's mouth. They act somewhat like a rubber band, except that nothing has to stretch them. They stretch themselves. The tentacles can do this because the cells of the tentacles can make themselves shorter or longer.

Some of the cells that line the inside of the hydra break up the food that the hydra catches. After the food is broken up, the other cells of the hydra can make use of it.

When the hydra is in danger, it pulls its body into a little knob. But how does it "know" when it is in danger? Some of the hydra's cells are able to sense when food or danger is near them. These cells are called **nerve cells.** They pass along a message to the cells that move the hydra's body.

Some of the hydra's cells support or hold together other cells. Such cells are sometimes called **connective cells.**

The hydra is called a many-celled animal because it is made up of different kinds of cells. These different cells do different jobs. The hydra is a *simple* many-celled animal. There are other many-celled animals, such as the chicken, that are more *complicated* than the hydra.

A Complicated Many-Celled Animal

The chicken is a much more complicated animal than the hydra. Like the hydra, the chicken is made of many cells.

A chicken has many different parts —among them are wings, neck, and legs. Can you name some other parts? When you take a closer look at these parts, you find they are made up of skin, flesh, and bone. A chicken also has lungs, a stomach, a gizzard, a heart, intestines, and other parts. The hydra has none of these.

Each type performs all necessary life functions.

Developing the Lesson: You might begin by asking the class:

- *Do you think it would be possible for one man to build an automobile all by himself?*

Discuss the problems involved, including construction of special parts, special tools and machines, special skills required. Determine the advantages of having different men, each skilled in his own way, to do different jobs. Speed, uniformity of product, and better quality would result.

Draw an analogy with living things by discussing an imaginary ameba grown to a gigantic size. Talk about the difficulties it would encounter in attempting to carry on its life activities. Point out that as its volume increased, it would become more difficult for oxygen and food to reach the interior. Removal of wastes would be slowed down. It would become more difficult for the ameba to react as a whole, to carry messages from one part to another in order to protect itself.

This discussion should lead to the conclusion that the efficiency of the organism would be greatly increased if, instead of one large cell, many small cells were used,

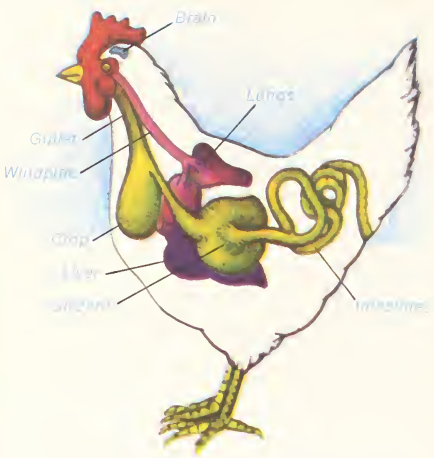
each one capable of doing a special type of work. Now turn to the work of the special cells of the hydra, described in the text.

Children will soon realize that as animals increase in size, their problems of living become more complex. Animals like the chicken have special organs for coping with these complexities.

- *What are some of these special organs?* (Pupils' answers should include the heart for pumping blood, lungs for breathing, wings for flying, eyes for seeing, special organs for digesting food, the brain, and the nervous system.)

It would be helpful to obtain charts of the hydra, the chicken, an earthworm, a cat, and a human, to point out the various special parts.

Follow-Up: Obtain cultures of the common water flea, daphnia, from the local pet shop. Put a few dahpnia into a culture of hydra. Children will be fascinated watching the hydra sting the daphnia with its tentacles, immobilize its prey, and then engulf and devour it. Hand lenses or microscopes may be used for this demonstration.



What are the parts of the chicken? Which parts are like those of your body?

Each part of the chicken is made up of different kinds of cells.

The fleshy parts of the chicken are the chicken's muscles. What do the chicken's muscles do? What do your muscles do? Each thread of chicken flesh is made up of many **muscle cells**. These are long, stringy cells that are held together by connective cells.

Examine an uncooked chicken leg. Notice how the skin is fastened to the flesh underneath it. What kind of cells hold the skin to the flesh? Remove some of the flesh from the bone. Separate some of the flesh into strings. How is the flesh fastened to the bone?

Chickens know what is going on around them. If they are frightened, they will cackle, try to fly, or run. An ameba and a hydra cannot do any of these things. Chickens can act in these ways because their nerve cells send messages to the muscle cells in their throats, wings, and legs. Muscles move when they receive messages from nerve cells to do so.

Your body has many of the same parts that a chicken has. You have skin, muscles, blood, bones, nerves, and a brain. All these parts of your body are made up of many different kinds of cells. These cells are very much like the special cells in the chicken.

The one-celled animals, such as the ameba, are the simplest. As the number of cells and the kinds of cells increase, the animals become more complicated. That is why the hydra is more complicated than the ameba and the chicken is more complicated than the hydra.

As you have read, all animals do certain things. You have also read that some animals can do more things than others. The hydra can do more things than the ameba. The chicken can do more things than the hydra.

You can do more things than the chicken. In fact, you can do more things than any other animal. You can talk, write, think, and even change things in the world around you. Only human beings can do all these things.

There are no other animals and no plants that can do these things. Yet all living things, no matter how complicated or how simple they are, must carry on the same life activities to stay alive.

Using What You Have Learned

1. Make a comparison of a whale and a dog. You might try to answer some of these questions: How does each one move? How does each one get its food? How does each one get oxygen? How are their shapes different? These books might help with your report:

   The First Book of Mammals by Margaret Williamson

   The Great Whales by Herbert S. Zim

   Paws, Hoofs, and Flippers by Olive L. Earle

   All About Whales by Roy Chapman Andrews

2. If you have an aquarium, you can watch amebas and hydras with the help of a microscope. You may be able to see other small animals and plants. With a medicine dropper, take some water from the bottom of your aquarium. Put a drop of water on a slide and put the slide under the microscope. Your class can take turns looking at the water under the microscope. Let each pupil tell what he sees.

ADDITIONAL ACTIVITIES

Make a culture of mixed animal life to study under the microscope. Place some straw, dried grass, or hay in a gallon jar of water, and add some dried mud from the edge of a pond or from around the foundation of the school building. Place the jar in a warm spot for a few days, and you should have thousands of specimens. If your water is chlorinated, allow it to stand open for a day or two before adding the grass and mud. An excellent book by Needham, entitled *Fresh Water Biology*, may be used to help identify the forms you will see.

Study the heartbeat of the daphnia. Mount the animal culture and a small drop of water in a bit of vaseline on a slide, and study it under the microscope. The action of the digestive tube of the tubifex worm is also observable through this same procedure.

Have children look up the function of a gizzard, which is found in chickens and other birds. Determine why this adaptation is needed by birds, but not by man.

Explore the systems of the human body and have committees make reports on the circulatory system, the digestive system, the skeletal system, and the nervous system.

Animals—How They Are Grouped

TEACHING SUGGESTIONS
(pp. 122–125)

● **LESSON:** What is the basis for modern classification of animals?

Background: Man classifies organisms on the basis of their structure. Organisms with similar structural characteristics are grouped together.

Other systems of classification have been used in the past. At one time, organisms were classified on the basis of habitat. The modern system of classification was introduced by the Swedish botanist Carolus Linnaeus, in 1753.

The plant and animal kingdoms are divided into a number of major groups, each of which is called a phylum. All the members of a phylum have certain characteristics in common. Each phylum is divided and subdivided into smaller and smaller groups. The smallest grouping of organisms is the genus. The individual kinds of similar organisms grouped into a genus are known as a species.

Each kind of organism has a scientific name which is the same the world over. The scientific name includes the genus and species names of the organism.

Learnings to Be Developed: The classification of animals is based upon comparative structures.

Let's suppose that somebody gives you a handful of coins and tells you to sort them. How would you go about doing it? You would probably pick out all the pennies and put them in one pile; then you would do the same for the nickels and dimes and all the other coins. When you were finished, you would have separate piles of pennies, nickles, dimes, quarters, and half dollars.

You might use other ways to sort your coins. You might sort them according to their dates or even according to the metal they were made of. You would have a way in which to sort every coin you collected. Each time you got a coin, you would know in which pile to put it. You would know because you would already have worked out a **system of classification** for your coins. A system of classifi-

Here you see many different stamps. How many different ways can you group these stamps? Each stamp is numbered. On a page in your notebook make a column for

cation is a way of sorting things into groups so that you know where each thing belongs.

Librarians also use a system of classification. Have you ever asked a librarian for a book about a famous person? She knows just where to look for the book. Have you ever noticed that all the science books are in one section of the library and all the story books are in another section? The system of classification used by librarians helps them find books quickly. When a new book comes into a library, they know just where to put it. Can you imagine a library without a system of classification?

The System of Classification Used by Scientists

Scientists who study plants and animals have a system of classification. Let's see if you can tell what their system is. On the next two pages are pictures of living things. How would you sort these living things?

each group. Place the number of each stamp in the proper column. When you finish, you will have a system of classification. How many different systems can you make?

Developing the Lesson: Draw the children's attention to the array of postage stamps at the bottom of pages 122–123.

- *What basis would be good for classifying the stamps?* (Color, nationality, denomination, subject matter, size, or shape are some plausible bases.)

Each child should be directed to follow the instructions over the pictures in completing the classification. Many systems will doubtless result. Emphasize the point that there is no single correct system.

If you have a set of world or state flags, asks the pupils to develop some systems of classification for these also. Again, many systems will be thought of.

Explain to the children that having many systems of classification is valid and useful. This applies to animal classification as well, but for universal usage in science, one or two are generally agreed upon as most useful.

Now have the children turn to the pictures on pages 124–125, and try to classify them.

Have them draw up a list of all the animals they might find in their neighborhood, and write the list on the chalkboard. It should include a variety of insects, worms,

birds, fish, and small and large mammals. Have them try to classify these animals.

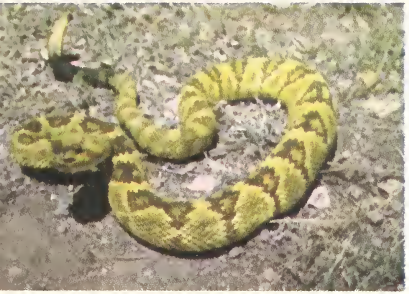
In doing these activities, be sure pupils understand why we need to classify animals. Remind them that there are over a million kinds of animals known to man, with new ones being discovered every year. Emphasize the need for orderliness. Living things are placed in groups for convenience in identifying and studying them.

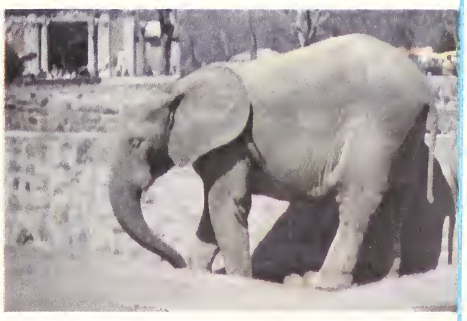
By now, children should be able to draw some conclusions about the most convenient ways of classifying animals. They should see that similarities and differences in structural characteristics—wings, legs, etc.—are one basis. However, careful questioning and discussion can lead them to the further discovery that surface resemblances are insufficient. Birds and butterflies both have wings, but they are placed in different categories. Worms and snakes seem very much alike in shape, but they belong to different classes. Try to bring the children to the edge of the discovery that animals are generally divided into those with and those without backbones. This is the subject of the next lesson.

CLASSIFY THESE LIVING THINGS

Here you see ten living things. Make a system of classification for these living things.

Do you have any trouble classifying these living things? Scientists once did. Can you tell why?





Follow-Up: This activity will help you to see how good you are at classifying objects into groups. The objects listed below have a number of characteristics which might be used to separate them into groups. There is one characteristic that could be used to classify the objects into four different groups. Four of the sixteen objects can be put in each group. The objects are:

Glass: bottle, test tube, water glass, window pane

Metal: spoon, scissors, tea kettle, door knob

Paper: package of kleenex, magazine, envelope, paper cup

Cloth: wool mitten, necktie, hair ribbon, wash cloth

TEACHING SUGGESTIONS
(pp. 126–128)

● **LESSON:** What are the two major divisions of the animal kingdom?

Background: The two major groups of animals to be studied in this lesson are the invertebrates, the animals without backbones, and the vertebrates, which have an internal skeleton and a jointed backbone.

Invertebrates are divided as follows:

Protozoa. The smallest invertebrates, all protozoa consist of a single cell.

Arthropoda. The largest group of invertebrates, arthropods have skeletons outside their bodies. Their bodies are jointed and they have legs. There are four major divisions of the Arthropoda phylum, as follows:

Centipedes and Millipedes. Centipedes have one pair of legs per body division, while millipedes have two pairs for each body division.

Crustacea. Crayfish, lobsters, shrimp, and crabs all have five pairs of legs.

Spiders. Spiders have two body divisions and four pairs of legs. Ticks and mites are included in this same division.

Did you put all the plants into one group and all the animals into another group? If you did, you are on the right track. Scientists sort all living things into two large groups—*Plants* and *Animals.*

How Animals Are Classified

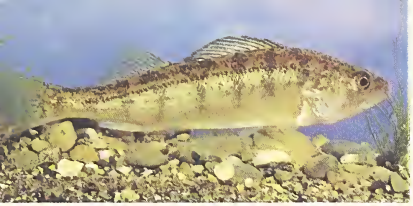
Scientists sort all animals into two large groups. They put all the animals that have backbones into one group and they put all the animals that do not have backbones into the other group.

Do you know what a backbone is? Feel the bones in the back of your neck. Run your fingers down your back. Do you feel the bones that make up your backbone? Your backbone is not one bone but 33 bones. Do you think that you could move as you do if your backbone was one bone?

If you stroke a cat or pat a dog on its back you can feel its backbone. Birds have backbones, and so do rabbits, squirrels, turtles, frogs, toads, and snakes. Snakes can move as they do because their backbones are made up of many bones. Some snakes have more than 300 bones in their backbones.

Make two columns on a piece of paper. At the top of one column write *Animals without Backbones.* At the top of the other column write *Animals with Backbones.* Into which column would you put these animals: hydras, chickens, amebas, earthworms, insects, oysters, birds, fish, human beings?

Each bone in your backbone is a vertebra (VER-tuh-bruh). The lower bones are fused together. The vertebrae protect the spinal cord inside your backbone. At the side, you see an end view of one vertebra.



1.

2.

ANIMALS WITH BACKBONES

1. **Fishes** live in water, breathe underwater, are covered with scales, and have air bladders and fins.
2. **Amphibians** breathe by means of gills when young and lungs when adult; they live in water when young and on land when adult.
3. **Reptiles** breathe with lungs; most of them have scaly skin.
4. **Birds** are animals whose bodies are covered with feathers, whose feet are covered with scaly skin, and who lay eggs with hard shells.
5. **Mammals** breathe with lungs, have hair covering their bodies, and get milk from their mothers.

3.

4.

5.

Insects. Insects have three body divisions and three pairs of legs.

All vertebrates have internal skeletons and jointed backbones. There are five main groups of vertebrates:

Fish. Fish are cold-blooded, breathe by means of gills, and are covered with scales.

Amphibians. Amphibians are cold-blooded and breathe by means of gills when young, and with lungs as adults. They are covered by a smooth, often slimy, skin. Frogs, toads, and salamanders are included in the class Amphibia.

Reptiles. Reptiles are also cold-blooded, but have lungs throughout their life cycles. They are covered with scales. Snakes, turtles, alligators, and crocodiles are the major divisions of the reptile class.

Birds. Birds are warm-blooded, breathe by means of lungs throughout their lives, and are covered with feathers.

Mammals. Mammals are warm-blooded, breathe by means of lungs throughout their lives, and have hair growing over their bodies. They feed their young with milk produced by mammary glands.

Learnings to Be Developed: Two large divisions of animal life are vertebrates and invertebrates.

Developing the Lesson: The existence of a backbone or, more correctly, a column of vertebrae bones, is not always apparent from outside observation.

- *Why is the backbone a good starting place for a simple classification?* (It roughly divides the animal kingdom into two large groups.)
- *Why would the brain not be a good basis for major divisions?* (Most animals have one.)
- *Why would eyes not be good for a grouping?* (Again, too many animals have them.)

To determine whether children have developed the concept of hierarchy in classification (that one or more subsets can be grouped together to form a set), ask the following questions derived from one of Piaget's tasks: Suppose all the animals in the world were to die. Would there be any birds left? If all the birds died, would there be any ducks left? If all the ducks died, would there be any animals left? Pupils' answers will give you some clues to their grasp of whole-part relations, essential to classification skills.

The two groups, *Animals with Backbones* and *Animals without Backbones,* are divided by scientists into smaller groups, which are then divided into even smaller groups.

As you study the pictures, you may be surprised at the way that the scientist groups animals. For example, he puts those animals that have feathers and lay eggs into the bird group. But did you notice that he does not list flying? Yet flying is often what we think of when we think of a bird. Ostriches and penguins are birds, but they do not fly. If we think that an animal must be able to fly to be called a bird, we will make mistakes when we group animals. Not all birds fly—

PATHFINDERS IN SCIENCE

Carolus Linnaeus

(1707–1778) Sweden

For centuries, men tried to explain how living things that looked alike were related. The ancient Greeks, for example, placed all living things on a kind of ladder of life, with man at the top of the ladder and other living things below.

In the 1600's, about 6,000 plants were known. One hundred years later, 12,000 more had been discovered. The great number of discoveries in the 1700's made it necessary to have a system of classification. Such a system was made by Carolus Linnaeus (lih-NAY-uss).

As a young man, Linnaeus collected many different kinds of animals and plants. When he tried to group them, he

Linnaeus classified plants chiefly according to their superficial sexual characteristics. Nevertheless, his classification of all known forms of life into classes, orders, genera and species is essentially the system in use today.

but *all birds have feathers,* and *all birds lay eggs.*

It is also true that some animals that fly are not birds. Can you think of any?

Whenever scientists discover a new plant or animal, they compare it with plants and animals they already know about. If the new plant or animal is like those in one of the groups that is already set up, it is put into that group. If it does not seem to belong to any group, a new group may be started.

You now have a good idea of how animals are grouped. Animals that are alike in certain special ways are grouped together. Plants are also grouped in very much the same way.

found very little order in the systems then in use. There was no plan of classification that was widely accepted at that time. There was also no agreement as to what names should be given to each of the living things.

Linnaeus decided to make up a system of classification which would give names to all of the plants and animals. He classified every known animal and plant and gave it a place in his system. He put each of the animals and plants into a special group. Each of the groups had living things in it that were alike in some way.

Although there have been many changes in Linnaeus' system, one part of his plan has remained—his system of *naming* each type of plant and animal. Linnaeus grouped plants that looked alike into a **genus** (JEE-nus). He also grouped animals that looked alike into a genus. For example, the genus that includes the house cat and other cats like it is called *Felis.* Next, Linnaeus made up a **species** (SPEE-sheez) name. The species name for house cat is *domesticus.*

Each living thing has a scientific name made from a genus name followed by the name of the species. The house cat is *Felis domesticus,* the lion is *Felis leo,* the leopard is *Felis pardus.* Can you tell the common name of *Felis tigris?*

Linnaeus' system is known as the **binomial** system (by-NOH-mee-ul). Binomial means "two names." Linnaeus used Latin for his system of classification, because in his time Latin was understood by scientists of all countries.

The work of Carolus Linnaeus has been a guide to scientists for almost two hundred years.

TEACHING SUGGESTIONS
(pp. 128–129)

Background: Carolus Linnaeus was born in Rashult, Sweden, on May 23, 1707 and died in Uppsala on January 10, 1778. He became interested in botany at an early age and, since the study of medicine and of botany went together at that date, he entered the University of Lund at the age of 20 to study medicine. He also studied at the universities of Uppsala and Harderwijk (the latter in Holland), traveled widely, and collected and classified a large number of plants.

All his life Linnaeus was an enthusiastic collector, author, and teacher. He wrote 180 books. His lectures at the University of Uppsala, where he became Professor of Medicine and Botany, attracted students from the entire world. Linnaeus' fame rests chiefly upon the system of classification he originated. He brought together the work of all his predecessors and unified it, in addition to discovering and classifying innumerable plants himself. The binomial system of classification, several examples of which are given in the text, is in universal use today, but with several modifications made in the light of more modern knowledge on the relationships between the various families of plants and animal life.

TEACHING SUGGESTIONS
(pp. 130–131)

○ ADDITIONAL ACTIVITIES:

This exercise will help children understand the need for using names as time-saving symbols.

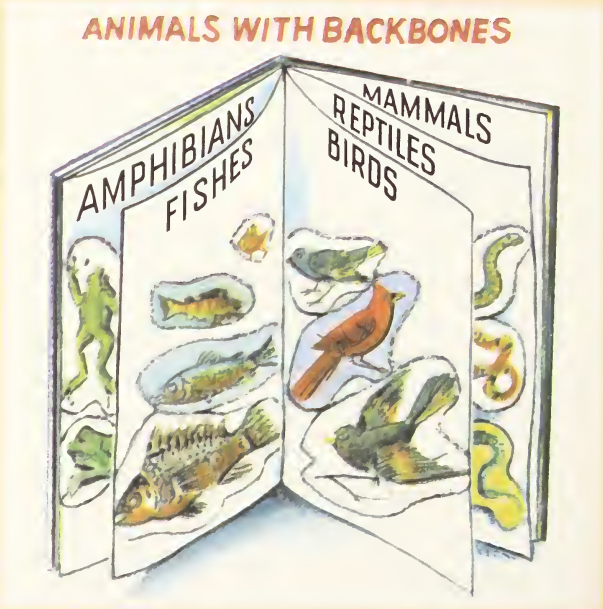
Prior to class time, write a number of simple messages containing the names of objects or persons familiar to the pupils on separate filing cards. Underline the key words. For example: "I broke an egg." "Did you hear the fire alarm?" "You will find it in the dictionary." "Meet me at Bob's locker."

Divide the class into groups, giving each group one card. Tell the pupils to rewrite the sentences using descriptions in place of the underlined words. Give the following example: "The pig is eating corn." An acceptable rewriting might be: "The four-legged animal with short hair, a twisted tail, small eyes, and an underslung jaw is eating something that is yellow, shaped like a club, and made up of pieces about a quarter of an inch long."

A second exercise can demonstrate the other side of this picture, the need for accurate descriptions. Collect the following pairs of organisms and distribute one pair to each group of children:

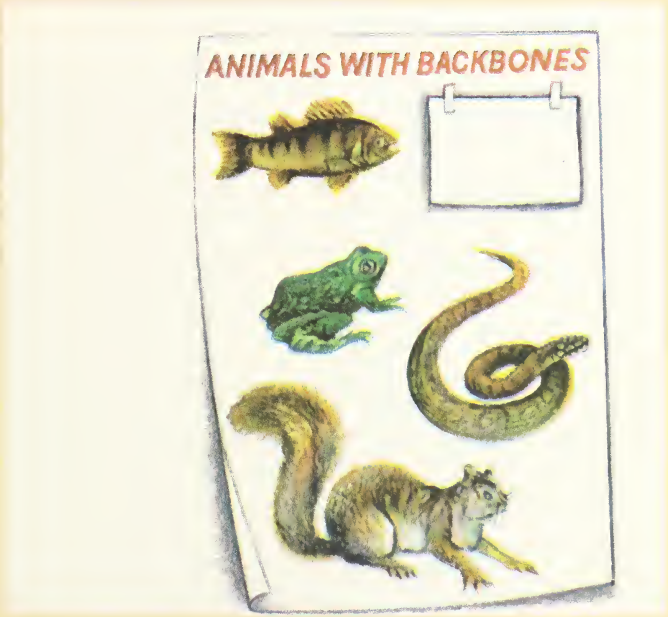
Using What You Have Learned

1. Make a scrapbook of animals. Everyone in the class can bring in pictures of animals. Have a separate section for each of the five main groups of animals with backbones. Find a picture of an animal in each group and write a short paragraph telling something interesting about the animal. Ask your librarian to help you find information. Remember that you should never cut pictures out of library books. Always ask permission before you cut a picture out of a book or magazine.



2. You can take a trip to the public library. Ask the librarian to show you where you can find books about animals, books about plants, and books about famous people. How does the librarian decide where to put each new book?

3. You can make a display in your classroom. Get a large piece of paper and paste pictures of animals from each of the five main groups on it. Now put a flap of paper over each picture. On this flap, write some clues about the animal that is under it. Have some classmates try to guess which animal is under the flap.



ivy and philodendron
cricket and cockroach
housefly and honeybee
grasshopper and katydid
frog and toad
earthworm and centipede
salamander and lizard
black oak leaf and white oak leaf
silver maple and sugar maple leaves
butterfly and moth

Give each separate organism a number. Ask pupils to write descriptions of the two organisms in their pair. Collect the descriptions and duplicate them.

The following day, distribute copies of the descriptions, without their identifying numbers, to all pupils, and place the numbered organisms on tables. Ask each pupil to match the descriptions with the proper organisms. If some descriptions fit both members of a pair, an excellent illustration is provided of the need for complete and accurate descriptions.

In the woods you can find a myriad of living creatures, such as sow bugs, millipedes, centipedes, worms, snakes, etc. Have pupils collect some of these in a wide-mouthed jar, and bring them into class for study with a hand lens. Try to classify these forms as vertebrates or invertebrates.

TEACHING SUGGESTIONS
(pp. 132–133)

Background: These two pages constitute a review of the concepts and terminology introduced in this unit.

What You Have Learned: This is a summary of the entire unit, with new words in boldface type.

Checklist of Science Words: Remind the pupils that there is a *Dictionary of Science Words* on pages 318–325. They should consult this dictionary whenever they are unsure of the precise meaning of a word.

WHAT YOU KNOW ABOUT

Animals—Simple and Complex

What You Have Learned

Living things use **oxygen,** use food, give off wastes, and produce more living things like themselves. Each of these activities is called a **life activity.**

Some living things are very simple and others are very complicated. **Biologists** are the scientists who study all living things. They make careful observations and **comparisons.** They have found out that there are certain ways in which all living things are alike. All living things are made of **cells.**

Scientists divide living things into two big groups—*plants* and *animals.* Then they divide these two big groups into smaller groups. The animal group is divided into two smaller groups. One of the groups is called *animals with backbones.* The other group is called *animals without backbones.*

This way of sorting living things into groups is called **a system of classification.**

Checklist of Science Words

Here are some science words you read about in this unit. Can you tell what you have learned about each one?

ameba	connective cells	muscle cells
biology	euglena	nerve cells
cells	hydra	survey
chrysamoeba	life activities	tentacles

What Is the Answer?

Write the numbers 1 to 5 in your notebook. Next to each number, write the answer to that question.

1. What four life activities do living things carry on?
2. What kind of cells support, or hold together, other cells?
3. Are there more animals or more birds in the world?
4. Are there more birds or more ducks in the world?
5. What are the five main groups of animals with backbones?

What's Wrong?

Look at the groups of pictures below. In each group, there is one picture that does not belong with the others. Tell which picture it is and why it does not belong.

What Is the Answer?

1. Oxygen getting, food getting, waste elimination, and reproducing.

2. Connective cells. In groups, they are called connective tissue.

3. Animals. Birds are included in the general category of animals.

4. Birds. Again, ducks are part of the class of birds. The phylum *chordates* includes the class *aves* (birds). *Aves* includes the order *anseriformes,* which are ducks, geese, and swans.

5. Mammals, birds, reptiles, amphibians, and fish.

What's Wrong?

Giraffes and elephants are mammals; the alligator is a reptile.

The turtle is a reptile and does not belong with the fishes.

The lobster is an invertebrate (an arthropod) which does not belong with the vertebrate birds.

TEACHING SUGGESTIONS
(pp. 134–135)

Background: These pages reinforce the concepts presented in the unit by suggesting activities that extend the pupil's ability to apply the learnings derived from the unit.

What Are the Words?

1. Muscle
2. Ameba
3. Survey
4. Life activities
5. Biology
6. Hydra
7. Chicken

Who Am I?

1. Whale
2. Penguin

You Can Read: Below is a list of books for your pupils.

Zoology: An Introduction to the Animal Kingdom, by R. Will Burnett, et al (Golden, 1958). Describes the important animals in each phylum. Studies the systems and life processes basic to all animals.

The Strange World of Animal Senses, by Margaret Cosgrove (Dodd, 1961). Describes how an animal's senses give it the information necessary to carry on its life activities.

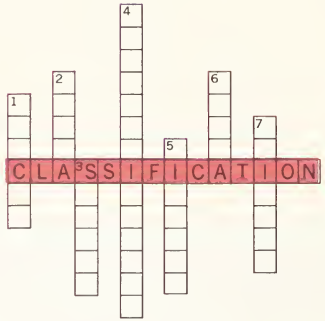
YOU CAN LEARN MORE ABOUT

Animals—Simple and Complex

What Are the Words?

Write the words in your notebook.

1. What kind of cell helps us to move?
2. What is a simple one-celled animal?
3. What are we making when we look for something and keep a record of what we find?
4. What do we call these things: using oxygen, using food, and getting rid of wastes?
5. What is the study of living things called?
6. What is a simple many-celled animal?
7. What is a complicated many-celled animal?



You Can Visit

If there is a zoo near your school, perhaps your class can visit it. When you are at the zoo, you can make a survey of the animals. Tell whether the animals are fish, amphibians, reptiles, birds, or mammals.

Try to find out which is the biggest animal in the zoo and which is the smallest animal.

Are the cages of the animals different? Do all the animals live in cages? Why not?

What has been done to make the living conditions right for the different kinds of animals? Think of heat, light, water, space, and food.

Your class can write a report about its trip to the zoo.

Who Am I?

If you guess on the first clue, you get 3 points; on the second clue, 2 points; on the third clue, 1 point.

1. I live in the water, but I breathe in air.
2. I am the biggest animal that lives in the ocean.
3. I am not a fish.

1. I cannot fly, but I am a bird.
2. I look as though I am wearing a man's suit.
3. I live near the North and the South Poles.

Now make up your own "Who am I?" questions.

You Can Read

1. *The Book of Reptiles and Amphibians* by Michael H. Bevans. Shows different kinds of animals.
2. *All About Birds* by Robert S. Lemmon. Many life stories of birds are told.
3. *Naming Living Things* by Sarah R. Riedman. How plants and animals are classified, and who classified them.
4. *The First Book of Mammals* by Margaret Williamson. Good description of many mammals.
5. *Exploring the Animal Kingdom* by Millicent E. Selsam. You will learn about animal classification.

Insect Engineers: The Story of Ants, by Ruth Bartlett (Morrow, 1957). This book not only describes the structure and social habits of ants but also tells how a youngster may collect and keep ants as pets.

Marvels and Mysteries of Our Animal World, by Reader's Digest (The Reader's Digest Association, 1964). A colorful book describing animals of every important order in every major class.

Science on the Shores and Banks, by Elizabeth K. Cooper (Harcourt, 1960). A guide for observing and collecting various forms of plant and animal life in shallow fresh and salt water.

Insects and Plants, by Irving and Ruth Adler (Day, 1962). Studies various plant-insect relationships.

NOTES:

Use this space for any additional teaching suggestions you may have.

Do You Remember?

Making *comparisions* is one way in which the scientist finds out more about the world around him. To make accurate comparisons, he uses special *instruments*.

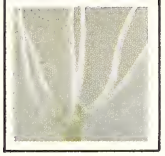
Galileo was one of the first scientists to observe, measure, time, and weigh things to find the answers to his questions. He kept records of all his work and compared his records after doing his *experiments* many times, to be sure of his results.

In an experiment, the things which the scientist keeps the same are called *controls*. The one thing that he changes is called the *experimental factor*. There should never be more than one experimental factor.

By doing experiments, scientists have found out a great deal about *energy*. Energy means the ability to do *work*. *Light, electricity, sound,* and *heat* are four kinds of energy. Energy can change its form. Heat energy can be changed into *mechanical energy*. *Stored energy* can become *energy in action*. Using a *force* takes energy. A force is a push or a pull on an object. When forces move an object, work is done and energy is used. We often use *simple machines* like *pulleys* and *levers* to help us move objects.

Gravity is one of the most important forces that start things moving. Gravity pulls things toward the earth. *Friction* is a force that makes things stop. When two things move against each other, there is friction.

Plants with *chlorophyll* use the light energy from sunlight to make food from water and *carbon dioxide*. The food that green plants make is a sugar called *glucose*. This process is



called *photosynthesis*. Glucose and the foods made from it have energy from sunlight stored in them.

Carbon dioxide enters green plants through tiny openings in the *leaves*. Water and minerals are absorbed through the root hairs on the *roots* and are carried through the *stem* to other parts of the plant. Plants store food in roots, stems, seeds, and *bulbs*.

Living things need energy to carry on their *life activities*. This energy comes from the burning of food within the living thing. The food for animals comes from green plants or from other animals that have eaten green plants. Everything you do takes energy which can be traced back to the sun.

Some living things are very *simple* and others are very *complicated*. But all living things are alike in certain ways. All living things use *oxygen,* use food, give off wastes, and produce more living things like themselves.

Scientists have a *system of classification* which places all living things into groups. The two big groups of living things are plants and animals. The animal classification is then broken down into *animals with backbones* and *animals without backbones*. Fishes, amphibians, reptiles, birds, and mammals are animals with backbones.

In this section of your science book, you have found out what energy is, how it is captured by green plants, and how it is used by living things. In the next section, you will learn about some of the forms of energy and how these forms are used by man.

NOTES:

Use this space for any additional teaching suggestions you may have.

KEY CONCEPTS

Key Concept 1. Events in the natural environment happen in an orderly rather than a haphazard way; man searches for laws to explain this order by observing, hypothesizing, checking his ideas, and rejecting those which do not square with reality.

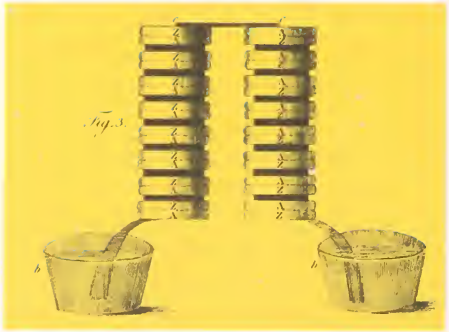
Key Concept 3. To find order in the natural environment, the scientist seeks basic units that can be put together in an almost infinite variety of ways; the cell and the atom are examples of such units.

Key Concept 4. All objects in the universe and all particles of matter are constantly in motion; man has discovered and stated the laws governing their motion.

Key Concept 5. The motion of particles helps to explain such phenomena as heat, light, electricity, magnetism, and chemical change.

CONCEPTS:

1. All matter is composed of atoms which in turn are made up of electrons, protons, and neutrons.



5

Other concepts appear under "Learnings to Be Developed" in each lesson found in the Teaching Suggestions.

Using Electricity

Electricity and the Atom

Different Kinds of Electricity

Electricity to Do Work

2. Unlike electric charges attract each other; like electric charges repel each other.
3. The force of electric charges decreases with an increase in distance.
4. An electric current is a flow of electrons.
5. An electric current can produce a magnetic field; a magnetic field is a force that can produce motion.
6. Electricity is safe to use, if used wisely.

PROCESSES:

- Observing—Pages 143, 145, 146, 151, 156, 157, 159, 160.
- Experimenting—143, 145, 146, 151, 157, 159, 160.
- Comparing—143, 145, 146, 151, 157, 159, 160.
- Inferring—144, 145, 146, 151, 157, 159, 160.
- Measuring—146, 159, 160.
- Classifying—150.
- Selecting (sources from recall)—140, 156, 158, 165, 169.
- Communicating—166, 167, 168.
- Demonstrating—147, 158, 168, 169.
- Explaining—145, 147, 155, 156, 161, 165, 167, 168.

TEACHING SUGGESTIONS
(pp. 140–142)

● **LESSON:** What are things made of?

Background: The phenomena of electricity and magnetism have been known from the time of the early Greek civilization, and probably even before. Thales of Greece (600 B.C.) gave descriptions of static electricity and of the magnetic activity of lodestones.

Even today, we do not have full explanations of electricity or magnetism, but we do have strong evidence to support the fact that they are closely related. We also have strong evidence leading to an explanation of the very structure of matter, in terms of electricity.

Learnings to Be Developed: All matter is composed of atoms, which in turn are made up of electrons, protons, and neutrons.

Developing the Lesson: Begin with a demonstration illustrating the electrical nature of matter.

1. Connect the leads of a galvanometer to a penny and a dime. Place the leads in a glass of salt water. The needle will deflect.

Every time you turn on a radio, or switch on a lamp, or use a toaster, you are using electrical energy. You use this form of energy to do all kinds of work. How many things in your house need to be plugged into an electrical outlet? Can you make up a list of things in your house that are run by electrical energy?

Electricity and the Atom

Electricity can be used to make things move, stop, and turn. Electricity is a form of energy. It can be used to run refrigerators and air conditioners, which make things cool. It can be used in kitchen ranges to make things hot, and in electric bulbs to give us light.

Electricity can do many things that are useful to us. Scientists, however, have another reason for being interested in electricity. In learning more about electricity, scientists understand more and more about the world around us.

When you hear the word *electricity*, you probably think about electric outlets and plugs, or batteries and wires. But have you ever heard thunder-and-lightning storms called "electrical storms"? And have you ever received an "electrical shock" when you walked across a rug and touched a door handle? You know, then, that there can be electricity even when there are no electric outlets and plugs, or batteries and wires.

To understand more about electricity, you must know something about the way scientists think of everything that fills space. **Matter** is the name that scientists give to things that fill space. Solids, gases, and liquids fill space. Mountains and rivers, trees and air, elephants and fleas all fill space, and they are all called matter. All matter—solid, liquid, and gas—has weight. **Physics** (FIZ-ikss) is the science that studies matter. **Physicists,** the scientists who study matter, believe that all matter is electrical.

Look carefully at the picture. How many things do you see that are run by electricity? Are things run by batteries also electrical? How can you tell?

Scientists believe that all matter is made up of **atoms.** Solids, gases, and liquids, mountains and rivers are all made up of atoms. Atoms are very, very small. They are so small that it would take a billion billion of them to fill a pinhole in this page. That is a bigger number than any of us can imagine.

Electrons and Protons

As small as atoms are, they are made up of even smaller parts, or particles. These are called **electrons** (ih-LEK-tronz), **protons** (PROH-tonz), and **neutrons** (NOO-tronz). Right now you will learn more about electrons and protons as you read on. In later grades, you will learn about neutrons.

2. Rub a balloon on a woolen skirt and place it on the chalkboard. It will adhere.

3. Place a newspaper on top of a smooth desk and rub it briskly with a woolen cloth. It will resist being peeled off the desk.

Look at the picture on page 141 and have pupils identify the electrical apparatus shown: toaster, clock, range, lights, percolator, mixer, etc. These are examples of the electric nature of matter being harnessed for the useful purposes of man.

When explaining the atomic models on page 142, notice that the orbits are not all in the same plane. This gives the effect of a cloud or shell around the nucleus. Such a model differs from the model of the solar system, where the orbits of all the planets are in approximately the same plane.

If the solar system model is called to the attention of the children, another point of difference might be mentioned. Planets do not jump orbits, but electrons do. Not only do they jump orbits, they can also jump in and out of the system, and become "free" electrons, or electrons not under the influence of an atom.

TEACHING SUGGESTIONS
(pp. 142–143)

● **LESSON:** How do we know there are two kinds of charges?

Background: The nature of static electricity was a matter for considerable discussion about the end of the 17th century. The fact that there were two different types of electrical charges was noted through experiments similar to the one in this lesson. Benjamin Franklin gave these two different charges the names "positive" and "negative." They had no mathematical significance in his day, and they have none today. They could have been called "alpha" and "omega" or any other set of names. Franklin associated the name "positive" with the charge on glass when rubbed with silk, and the name "negative" with the charge on rubber or amber (plastic in our experiment) when rubbed with fur.

Learnings to Be Developed: The behavior of charged objects suggests that charges are not all alike.

These are atoms. On the left, one electron moves around one proton. In the center, two electrons move around two protons and two neutrons. On the right, eight electrons move around eight protons and eight neutrons. What is the same about them all?

From the word *electron,* you might guess that there is something electrical about this tiny particle. There is. Scientists have discovered that every one of the small electrons has an electric charge. Every proton also has an electric charge. This means that each one of these particles puts forth its own electrical force. The force of these particles may be a *push* or a *pull.* The electrical charge of each one is very small, and so the force is small.

Two Kinds of Charges

Scientists have also discovered that these protons and electrons have different charges. Each proton has a **positive charge.** Scientists use the sign **+** to show the proton's positive charge. Each electron has a **negative charge.** Scientists use the sign **—** to show the electron's negative charge.

An atom has the same number of protons and electrons. But an atom can *lose* some electrons. Then it is left with more *protons* than electrons. The atom then has a positive charge. An atom can also *gain* electrons. If an atom gains some extra electrons, it has a greater number of negative charges. The atom then has a negative charge.

What happens to the combs in the first part of the experiment on page 143? Describe the way they act.

How Do We Know There Are Two Kinds of Charges?

What You Will Need

2 plastic combs
piece of fur
glass rod
piece of silk

How You Can Find Out

Part I

1. Make a little swing on which you can rest one of the combs.
2. Rub each comb with a piece of fur.
3. Put one comb on the swing and bring the other comb close to it.

Part II

1. Rub the glass rod with the piece of silk.
2. Bring the rod near the comb on the swing that you rubbed with fur.

Questions to Think About

1. What happens when you bring the combs together?
2. What happens when you bring the glass rod near the comb?

Developing the Lesson: The development of the experiment is simple and clear. Explain that various substances such as the plastic comb, glass, fur, and silk, all have different arrangements of atoms, and some give up electricity better than others. These differences in freeing electrons cause a build-up of electrons in one place, and a deficiency in another.

Background: Following are the answers to *Questions to Think About,* page 143.

1. The free or swinging comb will tend to be pushed away or repelled by the comb in the hand. This would indicate a force of repulsion, or "push."

2. There should be a noticeable tendency for the glass rod and the comb to come together. This is a force of attraction, or "pull."

TEACHING SUGGESTIONS
(pp. 144–145)

LESSON: What happens when things have like charges?

Background: The question of the mechanics of transfer might be raised by your brighter pupils. How do the electrons come off through rubbing? At this level it would be best to explain the process in terms of heat energy. When a substance is heated, its electrons, atoms, and molecules become excited or more energetic. When an object is rubbed, the friction supplies heat, and the electrons on the surface of the object pick up enough energy to free themselves from their atoms. Electrons thus build up on the silk cloth, while the glass rod becomes deficient in electrons. In the case of the comb and fur, the excess electrons come from the fur, and build up on the plastic.

Learnings to Be Developed: Like charges repel each other.

Developing the Lesson: Work through the experiment as indicated in the text on page 145.

It should be noted that dry, cold air is usually ideal for demonstrations on static electricity. Warm air holds more moisture, and the water vapor discourages the

Things that are electrified do not always push away from each other. In the second part of the experiment on page 143, the glass rod and the comb pulled toward each other. The "push" or "pull" of the combs and of the rod was caused by the electric charge of the atoms in the combs and in the rod.

From these experiments, you can see that an atom can act in two ways. It can pull toward another atom or it can push away from another atom.

If the two atoms have different charges, they will pull toward each other. What do you think happens when two atoms with positive charges are brought together? What do you think happens when two atoms with negative charges are brought together?

Look at the picture of atoms on page 142. Protons are in the center of each atom and have a positive charge. Electrons circle around each center and have a negative charge. Electrons are in **orbit.**

Electrons do not always stay in orbit. For example, when you rubbed the glass rod with silk, some of the electrons of the rod went over to the silk. The rod lost some of its negative charge and became positive.

How Like Charges Act

You remember that the two plastic combs received extra electrons when they were rubbed with fur. Both combs then had a negative charge. When the two combs were brought together, they pushed away from each other because both had the same kind of charge. But why did the rod and comb pull toward each other when they were brought together?

What happens if two things with positive charges are brought together? To find out, do the experiment on page 145.

If two objects both lose electrons, each is left with more protons. Each then has a positive charge. The objects push away from each other. *When any objects have the same kind of charge, they will push away from each other.*

How Unlike Charges Act

You now know what happens when the charges are both the same. What happens when the charges are different? Try giving a plastic comb a *negative* charge (rub it with fur so that it gains extra electrons). Then give a glass rod a *positive* charge (rub it with silk so that it loses electrons). The plastic

What Happens When Things Have Like Charges?

What You Will Need

2 glass rods piece of silk

How You Can Find Out

1. Hang one of the glass rods on the back of a chair with a piece of string.
2. Rub each of the rods with the piece of silk. (The glass does not hold its electrons tightly. Both rods will lose electrons. Now the rods have more protons than electrons.)

Questions to Think About

1. What happens when you bring the second glass rod near the first one?
2. Explain what happened in terms of + and − charges.

comb and the glass rod will pull toward each other. *Objects with different charges pull toward each other.*

Try rubbing a balloon on wool. The balloon will get some extra electrons. It will become negatively charged. But where do these extra electrons come from? The wool gives them up. The wool loses electrons and becomes positively charged. Now the balloon and the wool have charges that are not alike. Let the balloon rest on the wool where you have been rubbing. Take your hand away. What happens?

build-up of charges. The invisible droplets, or molecules of water, provide a conductor in the air, and the charges leak off the rods or combs.

Background: Following are the answers to *Questions to Think About,* page 145.

1. The action should be the same as when the two combs were in proximity, in the experiment on page 143. The cause is also the same. The rods were holding identical charges and exhibited repulsion.

2. Rubbing the glass rod caused a transfer of electrons, with a − charge, to the silk. The silk became negatively charged. The glass rod, with a loss of electrons from its surface, became electrically unbalanced. It had excessive + charges along its outer surface.

ADDITIONAL ACTIVITIES:

Have pupils blow up toy balloons. Let them try to place them on the wall. Now have them rub some of the balloons on their hair, or on fur, and place these on the wall. The balloons will stick to it.

Now let them see what happens when they bring two rubbed balloons together. Discuss why they repel one another.

The balloon, with the — charge, and the wool, with the + charge, stick together. Two objects with different charges attract each other.

Shortly, the balloon falls from the wool to the floor. The balloon and the wool are no longer pulled toward each other. The extra electrons have left the balloon and gone back to the wool. The balloon and wool now have their usual number of electrons. When electrons and protons are in balance, objects are not pulled toward or pushed away from each other.

EXPERIMENT

Does Distance Affect the Pull Between Two Objects?

What You Will Need

2 balloons
2 glass rods
piece of wool
piece of silk

How You Can Find Out

1. Rub two balloons with wool.
2. Place the balloons far apart on the table.
3. Bring the balloons closer together.
4. Next, rub the glass rods with silk. First hold them far apart. Then, slowly move them toward each other.

Questions to Think About

1. What happens when the balloons are far apart?
2. What happens when the balloons are close together?
3. What happens when you hold the rods far apart?
4. What happens when you bring the rods closer together?

TEACHING SUGGESTIONS
(pp. 146–147)

LESSON: Does distance affect the pull between two charged objects?

Background: The first successful attempt at placing the study of electricity on a quantitative basis was made by Charles Coulomb, a French engineer, in 1785. Coulomb designed a delicate torsion balance, with which he was able to show that two like charges repel each other (or unlike charges attract each other) with a force directly proportional to the strength of each charge, and inversely proportional to the square of the distance between them.

Learnings to Be Developed: The force of an electric charge decreases with an increase in distance.

Developing the Lesson: The procedures in this experiment can be varied to suit your classroom conditions. It might be possible to suspend the balloons from a wire and slide them along the wire after you charge them. You might suspend the glass rods in a similar fashion.

Background: Following are the answers to *Questions to Think About,* page 146.

1. Reactions between them are not too noticeable.

Distance Makes a Difference

You have already read that when charges are not the same, objects are pulled toward each other. The closer the two objects are, the more they are pulled together. You saw this happen in the activity on page 146.

To remember what you have learned, think of the following summary. *The farther apart the charged objects are, the less they will pull toward each other. The closer the unlike objects get to each other, the more they will pull toward each other.*

You can show that a neutral object is attracted by the electrical field of a charged object.

Attach a pith ball, or puffed cereal grain, to a string suspended from a ringstand. Rub a glass rod with a piece of silk and place the rod near the pith ball. The ball is first attracted to the rod, and then falls away. This occurs because the rod loses electrons to the silk, and becomes positively charged. The pith ball, which was neutral, loses electrons to the rod. After the electrons have been discharged, the ball becomes positively charged. The glass rod readily loses its negative charge to the ground, via the hand of the person holding it. Since both objects are now positively charged, they repel one another.

Using What You Have Learned

1. You can bend a stream of water. Open a faucet so that just a thin stream of water comes out. Rub a comb with fur, nylon, or wool. Hold the comb near the stream of water.

   What happens? Why?

2. Press the toe of a nylon stocking against the wall. Rub the stocking with a clear plastic bag. Hold the stocking in the air and you will see it fill out as if someone's leg were in it.

   Can you tell why this happens?

3. You can make pieces of paper dance. Put a piece of glass on two books. From a sheet of writing paper, cut out pieces of paper about ½″ long and ½″ wide, and put them under the piece of glass. Now rub the glass with a piece of nylon or silk.

   What happens to the pieces of paper? Why do you think this happens?

2. As the distance decreases, there is a stronger tendency to repel. At some point it will be fairly difficult to have them touch each other unless an outside force, such as your hand, acts on them.

3–4. The actions of the glass rods duplicate the actions of the balloons. Since the mass of the rod is greater than that of the balloon, reactions will differ in degree.

The following material will provide you with information for the *Using What You Have Learned* section on page 147.

1. The neutral water is attracted by the charge, and bends toward the charged object.

2. Both layers of the nylon stocking picked up a charge. Their tendency to repel causes them to take a position as far apart from each other as possible.

3. The pieces of paper dance up and down. They are attracted to the charged glass because they are neutral. When they come in contact with the glass, they pick up the charge and are repelled. Then they move away from the glass, lose the charge, and the process starts again.

Static electricity does not supply energy to perform work. However, it has been important to the study of what electricity does and how we can use it.

Different Kinds of Electricity

TEACHING SUGGESTIONS
(p. 148)

● **LESSON:** What is static electricity?

Learnings to Be Developed: In static electricity, friction makes electrons go from one object to another. When the electrons reach the second object, they remain at rest.

Developing the Lesson: The most dramatic example of static electricity is the lightning storm. Encourage children to describe the events of such a storm, and then discuss the causes. Point out to them that static electricity is produced by the friction of rain drops in clouds. Lightning is the giant spark produced when this electricity jumps from one cloud to another, or from a cloud to earth. In connection with this lesson, children may wish to learn more about the use of lightning rods. They may also benefit from reading about Benjamin Franklin's experiments with kites.

ADDITIONAL ACTIVITIES:

Make a toy based on static electricity. Obtain a flat transparent plastic box. Place some small pieces of light string and bits of aluminum foil inside. Rub the cover with a piece of wool. On a cool, dry day, the contents will be attracted to the top of the box.

Now that you know something about the way electrons move, you can learn about the different kinds of electricity.

Static Electricity

When you make electrons move from one object to another you are making a kind of electricity. One kind of electricity is called **static electricity**. Static electricity is the kind made whenever two objects are rubbed together. The friction makes electrons go from one object to another. Static electricity is not very useful to us. It will not run motors or light lamps.

Although static electricity is not useful to us, we sometimes feel its effects. When you walk across a wool rug in the wintertime and touch another person, you sometimes get a small electric shock. Electrons from the wool rug rub off on you, and you then get a small charge of static electricity.

When you comb your hair on dry winter days, your hair sometimes seems to crackle and stick to the comb. Some of the electrons of your hair have rubbed off on the comb, giving it a — charge of static electricity. What kind of charge does your hair have after it is combed?

Static electricity is the electricity that is observed when a positive or negative charge builds up in one area and a small shock, spark, or motion of visible particles occurs

Current Electricity

The kind of electricity that we use to help us with our work, or light our way, or heat our houses, is called **current electricity.**

Current electricity is different from static electricity. In static electricity, friction makes electrons go from one object to another. When the electrons get to the second object, they remain at rest. But in current electricity, a continuous flow of electrons enters an object, travels through it, and then passes out of it.

Some materials make good paths for flowing electrons. These materials are called **conductors** (kun-DUK-terz). A copper wire is a good conductor.

In each atom of copper, there is one loose electron which can become free. The word "free" simply means that the electron can be pushed out of its usual orbit in the atom. When this happens, the electron is no longer attached to its atom. The electron is free to move about by itself.

Loose electrons cannot leave their atoms unless something pushes them. One way to start loose electrons moving along a wire is to use a **dry cell** to push

These materials are all conductors. What part of each is the conducting material? How are you able to tell?

The metallic exposed part is the conductor.

The term "static" represents a state of build-up in which a constant flow of electricity does not take place.

TEACHING SUGGESTIONS
(pp. 149–150)

● **LESSON:** How is current electricity different from static electricity?

Background: The flow of an electric current through wires is comparable in many ways to the flow of water through pipes. The flow of electrons through wires requires a push or force strong enough to overcome the resistance in the wire, just as the flow of water requires a push strong enough to overcome the resistance in the walls of the pipe. Water descending from Niagara Falls receives a tremendous push in direct proportion to the height from which it falls. In the case of electricity, the current is dependent upon the difference in concentration of electrons between two bodies. This is known as difference in potential, or voltage. Where no difference in potential exists, no current will flow.

In order for electricity to flow in a wire, the current travels in a continuous path and in a complete circuit. Wires lead from the source of electric current to the electrical appliances in your home, and from the latter back to the electric generators. When you flick on a switch, you are completing the circuit permitting the current to

flow to and from household appliances. You break any circuit when you turn the switch off.

The flow in a conductor is really a jumping of free electrons from atom to atom. There is no flow in the sense of an open conduit.

Learnings to Be Developed:

In current electricity, a continuous flow of electrons enters an object, travels through it, and passes out of it.

Current electricity does work for us.

Developing the Lesson: You can introduce this section with an in-school field trip to trace electric current from power lines in the street to the outlets and lights in the classroom. It would be advisable to have the custodian help you here. Visit the point where the electricity enters the building, where it is metered, where the control distribution panels are located, etc.

ADDITIONAL ACTIVITIES:

Have a representative of the utility company to address an assembly on safe electric practices in the home.

A library research team could report on the early work of Faraday, Franklin, and Galvani, and on electric currents and static electricity.

them. On page 154, you will learn more about how a dry cell works. As you will see, there are materials in the dry cell which release free electrons of their own. When a copper wire is attached to a dry cell, the free electrons of the cell start pushing upon the loose electrons in the copper atoms of the wire. Millions of loose electrons from the copper atoms in the wire are pushed until they become free also. The dry cell pushes all the free electrons in the same direction.

Current electricity is really the continuous flow of free electrons. These electrons are all pushed along a path.

An electric current can flow easily through most kinds of metal. This is because most metals have loose electrons in their atoms, which can become free if they are pushed. That is why most metals are good conductors.

Materials that do not allow electrons to move easily are not good conductors. They are called **insulators** (IN-suh-lay-terz). Thread, rubber, and glass are insulators.

Using Current Electricity

A scientist named Alessandro Volta (ah-leh-SAHN-droh VOHL-tah), who lived from 1745 to 1827, made the first electric cell. You can make an electric cell something like Volta's.

In the next experiment, you will find that when silver (dimes) and copper (pennies) are placed in salt water, electrons leave the silver and move to the copper. Other metals can be used to make an electric cell.

These materials are all insulators. What part of each is the insulating material? How are you able to tell?

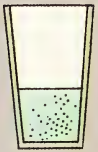
How Can You Make an Electric Cell?

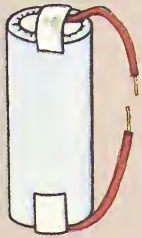
What You Will Need

8 clean pennies	paper tubes for pennies	pair of scissors
8 clean dimes	blotting paper	cellophane tape
sandpaper	glass of salt water	2 six-inch wires

How You Can Find Out

1. Sandpaper all of the coins lightly to make them clean.
2. Put eight pieces of blotting paper, each about the size of a dime, into the glass of salt water to soak.
3. Make a sandwich of pennies, dimes, and soaked blotting paper in your paper tube. Stack them in this order: penny, blotting paper, dime.
4. Cut the paper tube off at the last dime on top.
5. With the cellophane tape, fasten one of the short wires against the bottom penny and the second wire against the top dime.
6. Touch the other ends of the two wires to your tongue.





Questions to Think About

1. What happens when you touch the wires to your tongue?
2. What is the name given to this kind of electricity?

TEACHING SUGGESTIONS
(pp. 151–152)

● **LESSON:** How can we make an electric cell?

Background: The work of Alessandro Volta is being duplicated in this experiment. We usually refer to this device as a dry cell. It should be noted that the dry cells used for flashlights and toys are dry only on the outside. The sealed interior contains a moist paste of chemicals, which performs the same function as the salt water solution in this experiment. The two substances in a commercial dry cell which take the place of the copper and silver of the coins are carbon and zinc. This will be discussed further on page 154.

Following are the answers to *Questions to Think About,* page 151.

1. A slight salty taste or metallic sensation is noticed, accompanied by salivation. The acids on the tongue conduct the current.

2. Current electricity.

Learnings to Be Developed: Chemical energy can be changed into an electric current.

Developing the Lesson: Prepare the materials and emphasize the fact that the metals are dissimilar—copper and silver. In practice, any two different metals will produce

the desired results. The paper coin tube can be obtained at most banks. Its purpose is simply to hold the stack of coins in order. Before any testing of your battery is done, be sure the uppermost coin is a different metal from the lowest one.

Point out the distinction between a cell and a battery. In common usage the terms are interchangeable, but in the strict sense a cell is a single unit, while a battery is a series of cells, such as we have here.

PATHFINDERS IN SCIENCE

Alessandro Volta

(1745–1827) Italy

One day in 1786, an Italian biologist named Luigi Galvani was dissecting a frog in his laboratory. His knife touched a nerve in the dead frog's leg. The leg jumped. Galvani tried to find out why this happened.

Galvani reasoned that all animals, whether they are dead or alive, have electricity in them. He reasoned that electricity was made when he touched the frog's leg with his knife.

However, another Italian scientist, Alessandro Volta, thought differently. Volta tried to repeat what had happened in Galvani's experiment, but instead of using a frog, he used himself. He placed a piece of tin on top of his tongue and a

The work of Galvani, a scientist, interested Volta in finding out how electricity is made. After many experiments Volta was able to demonstrate how electricity is produced.

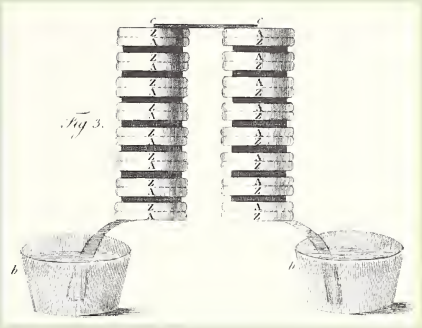
silver coin under his tongue. Then he let a copper wire touch both pieces of metal at the same time. When he did this, he got a sour taste in his mouth. The taste lasted only as long as the tin and silver were connected by the copper wire. This showed that there was a flow of electricity from one place to another.

Volta repeated the experiment, but this time he used a piece of cardboard soaked in salt water instead of using his tongue. Again, an electrical current was made.

From these and other experiments like it, Volta reasoned that the metals not only acted as conductors of electricity, but were actually making their own electricity.

How does all this explain why the frog's leg had jerked when Galvani was dissecting it? Volta said that Galvani's knife was made of one kind of metal, and the box which held the frog was made of another. The frog acted in the same way as the piece of soaked cardboard. It allowed an electrical current to be made. Without knowing it, Galvani had used the right metals and the correct ways to set up an electrical current. When the two different types of metals were in contact, enough electricity was made to cause the frog's leg to jump.

Volta reasoned that if *two* pieces of different metals and a soaked piece of cardboard could produce a little electricity, then *many* pieces of metal and soaked cardboard would produce a great deal more electricity. After many experiments, Volta built the "pile," which was the first electric battery.



Volta's own drawing shows how he set up a series of silver and zinc discs, separated by brine-soaked paper, for his experiments.

Volta had discovered how to use chemicals to create a mild but steady flow of electric current. His discovery made it possible for electric current to be supplied for many of man's needs. His invention opened the way for other scientists to invent the telegraph, the telephone, the radio, and thousands of other machines.

The word "volt," which is a unit of measurement in electricity, is now used by scientists to honor Volta's work.

TEACHING SUGGESTIONS
(p. 153)

Background: Alessandro Volta was born in Como, in the north of Italy, on February 18, 1745, and died there on March 5, 1827. He was appointed Professor of Physics at a local school when he was 29.

In those years, to experiment with static electricity was the rage among scientists, and Volta experimented also. He invented the electrophorus, a device much like a modern condenser with which a static charge could be built up by rubbing. The static charge was then used in electrical experiments.

As a result of his invention, Volta was appointed Professor of Physics at the University of Pavia, where he remained for 25 years. He became interested in the experiments reported by Galvani, with the result, as related in the text, that in 1800 he invented the battery.

The importance of this discovery cannot be underestimated. For the first time, a steady current of electricity could be made to flow, instead of being discharged instantaneously as with static electricity.

TEACHING SUGGESTIONS
(pp. 154–158)

● **LESSON:** How do dry cells work in a circuit?

Background: The model of the electric cell, which the children constructed earlier (see page 151), must possess energy in order to do the work of moving electrons. This energy is chemical in its source.

The typical dry cell is only dry on the outside. The sealed interior contains a moist paste of two or three chemicals. Usually these are ammonium chloride, powdered carbon, and manganese dioxide.

The ammonium chloride helps remove electrons from atoms of the carbon rod in the center of the cell.

The powdered carbon helps to provide a partial conductor across the inside of the cell, and reduce the work of the cell in moving electrons. It reduces internal resistance.

The manganese dioxide prevents a build-up of hydrogen gas around the carbon rod by changing it to water—it oxidizes hydrogen.

The dry cell is one form of *voltaic cell*. Voltaic cells consist of two dissimilar conductors (electrodes) immersed in a solution of acid, base, or salt (an electrolyte). In a

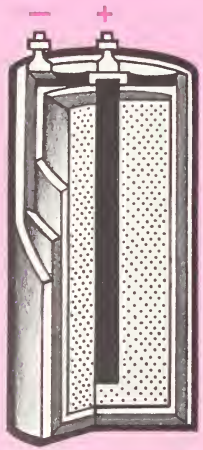
Dry Cells of Different Sizes

Here are three different sizes of electric cells called *dry cells*. Do you know what is inside each one?

First find a used dry cell. The large size will be easier for you to open and to see. Open it carefully. You may need help from the school custodian.

The inside of the dry cell is filled with a paste-like material. There is a solid black rod in the middle. The metal, the paste-like material, and the solid rod act like the pennies, dimes, and salt water that you used to make electricity.

A section through a dry cell.



Why must the bulb be connected as shown?

The dry cells in the picture are of different sizes. Which do you think will make the brightest light? To find out, get three dry cells like the ones in the picture. Connect each of the dry cells to a small flashlight bulb as you see in the picture. What happens?

Electricity from the larger dry cell does not make the bulb any brighter than electricity from the smaller dry cell. Each of these cells produces the same amount of energy. But the larger cell will give off energy for a longer time than the smaller one. Why?

The amount of push behind the electrons in these dry cells is very small. You know it is not enough to shock you. In the electricity in your home, the amount of push on the electrons is 80 times greater. It can knock you over or even kill you. That is why we must use electricity in our homes and schools with great care.

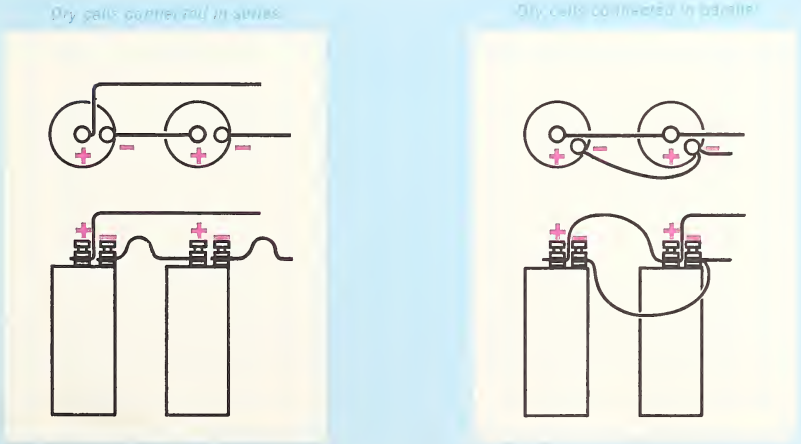
Using More Than One Dry Cell

Do you increase the amount of push upon the electrons when you use two dry cells? If you connect two cells, as you see in the picture, the flow of free electrons will move twice as fast as when you use only one cell. The lamp will burn more brightly, then, but the cells will be used up more quickly than if only one cell were used at a time.

When two dry cells are connected as in the picture below, the electrons have only as much push as one of the dry cells. Your lamp will not burn as brightly as when you connected the cells before. But your dry cells will keep the lamp burning twice as long.

To light several lamps, you should use two dry cells to get twice as much push. How would you connect them?

Tell what happens if you connect the cells as shown in the pictures below.



cell like the one on page 154, electrons accumulate on the zinc and the excess are conducted outside the cell by a conducting wire to the carbon. The electron flow is from the zinc cup, through the conductor, to the carbon rod.

Learnings to Be Developed:

Large dry cells last longer than small ones, but they both have the same electrical force.

A battery of dry cells can be arranged to increase the electrical force or to last longer.

A circuit is a closed path for the flow of electrons.

Developing the Lesson: Encourage children to bring in devices operated by low voltage dry cells, such as electrical games or toys. Let them take these apart, examine them, discuss them.

Give children the opportunity to put together a simple, complete circuit with a dry cell, some wires, and a bulb or bell. In doing this, they will learn to trace the path of the electric current from one of the terminals of the dry cell to one of the terminals in a light socket or bell socket, and from the other terminal in the socket back to the dry cell.

Point out to your pupils that every time they flick a light switch on

or off, they are actually closing or opening a circuit. Demonstrate this by placing a knife switch in the circuit they have just constructed. Show what happens when the switch connects or disconnects the circuit.

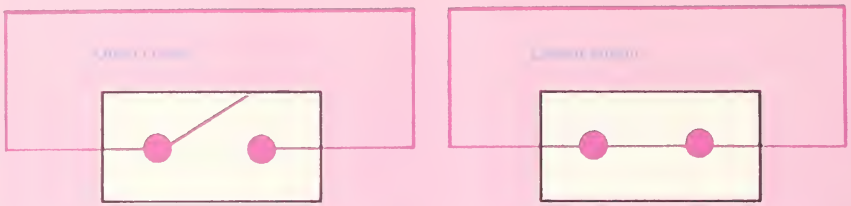
Ask children to devise other ways of turning the current on and off, such as tacking strips of metal on both ends of a piece of wood.

ADDITIONAL ACTIVITIES:

Have pupils examine fuses, some new and some blown, to determine which ones are good and which are bad. Place the fuses in a circuit with a dry battery and bulb. Where the metal strip in the fuse has been broken, children will observe that electricity will not pass through, and the bulb will not light up.

Children can make a simple fuse by mounting a thin strip of aluminum foil on a block of wood and placing it in a circuit with a flashlight bulb and dry cell battery. Connecting the two terminals of the bulb socket with a bare wire will produce a short circuit, which will in turn produce enough heat to melt the fuse.

Discuss the value of fuses as protection against fire through overloading of circuits.



Which of these pictures shows an open circuit? Which shows a closed circuit? Through which will electric current flow? How can you be certain of your answers?

Open and Closed Circuits

Remember, electrons must move through something after they leave the dry cell. The path through which they move is called a **circuit** (SER-kit). The circuit must begin and end at the dry cell.

A circuit that has no openings in it is called a **closed circuit.**

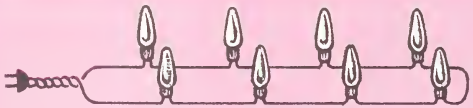
When the circuit has an opening in it, it is called an **open circuit.** When the circuit is open, the current will not flow through.

Look at the picture below. If you take one of the bulbs out of its socket, what happens? Can you tell why? What has happened in the circuit? Where did it happen? This kind of circuit is called a **series circuit.** Can you tell why?

Now connect the lamps as in the picture below. Take out one of the lamps. What happens? Trace the circuit and you will see that it is still closed. That is why the other lamps will still burn. This kind of circuit is called a **parallel circuit.** Can you tell why?

How are Christmas tree lights connected? Have you seen other strings of lights? How are they connected? Why are they connected that way?

What kind of circuit does each picture show? How are you able to tell? Tell where each kind of circuit is used and why it is used in the type of situation you name.

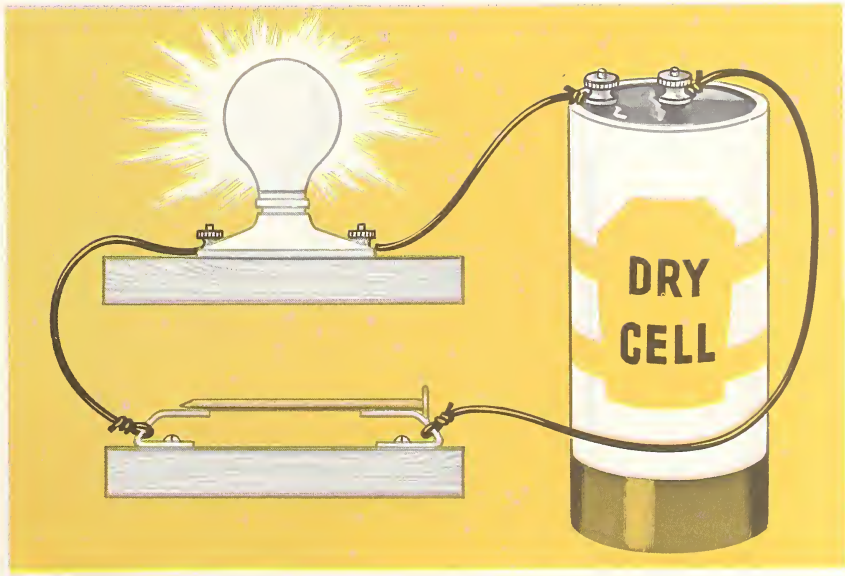


Using What You Have Learned

1. Here is a way to find out if something is a good conductor of electricity.

Bend two metal pieces in half and punch holes in them for screws. Screw the pieces of metal to a wooden block about 2 inches apart. Now connect the dry cell in the way that is shown in the drawing.

You now have a complete circuit except for the space between the metal pieces. If a conductor is laid across this space, the light will go on. If an insulator is laid across the space, the light will not go on. Try different kinds of materials to see if they will conduct electricity.



Background: The following is additional information for *Using What You Have Learned.*

1. All matter can be classified as either conductors, or semiconductors. Conductors contain charges which are relatively free to move over large distances in the material. In semiconductors, most of which we call nonconductors, there are no such charges. All electric charges (electrons, ions, etc.) in the material can be displaced only over small atomic distances.

Below are some common substances listed in order of electrical conductivity, with silver as the best conductor.

1. silver
2. copper
3. aluminum
4. tungsten
5. nickel
6. brass
7. iron
8. platinum

The conducting ability of substances is dependent on their atomic structure and their molecular arrangement. Dry sodium chloride (table salt) is a nonconductor, but in water it is excellent. In solution, its ions (+ and − particles) dissociate and perform as independent particles.

2. One of the most important achievements of modern technology is the so-called solar cell, which converts light directly into

electricity. When exposed to sunlight or incandescent light, these cells cause motion of electrons across a silicon wafer.

Unlike the usual battery which uses stored chemical energy, the silicon solar cell never wears out or decreases in its power capacity. Its power depends only on the amount of available light. Vanguard I, Explorer VI, Telstar, and other space probes which transmit across millions of miles have their radio and TV signals produced by such cells.

Investigate also the storage battery and newer fuel cell.

3. A flashlight is simply an efficient organization of the materials in this activity. Adding a reflector and lens controls the light beam.

ADDITIONAL ACTIVITIES:

Construct one of the following: An electrical quiz game, a simple galvanometer to indicate flow of electrons through a wire, a test device for conductors and nonconductors, an alarm system which goes off when a door is opened, a circuit in which either of two switches can light the same lamp, or a simple fuse.

Some pupils might find out how a storage battery operates and explain it to the rest of the class.

2. What other kinds of electric cells are there besides dry cells? How are they different from dry cells?
3. You can make your own flashlight. You will need two flashlight dry cells, a piece of paper that is long enough to cover them, bell wire, and a flashlight bulb. Wrap one end of a piece of bell wire around a flashlight bulb. Place the cells and wire as you see them in the picture.

   Now roll the dry cells and the wire in the paper, and put two rubber bands around the roll. Also, put a rubber band around the long part of the roll to make sure both dry cells stay together and touch each other.

   To make the flashlight work, you touch the loose end of the wire to the bottom cell, and the bottom of the flashlight bulb to the top of the other cell, as shown in the picture.

Electricity to Do Work

We use some electricity in our homes to heat things, such as toasters and irons. But this is not using electricity to do *work*. You have learned on page 29 that work is done when a force moves an object. How can we use electricity to do work for us? We do this by using **electromagnets** (ih-lek-troh-MAG-nits).

An electromagnet is a piece of metal with a coil of wire around it, which becomes a magnet when an electric current flows through the coil.

Electromagnets

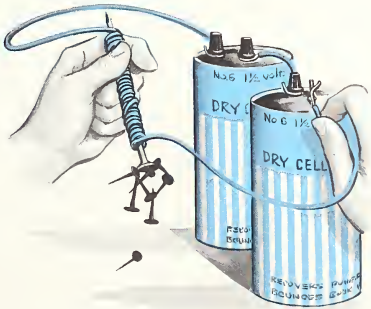
Electromagnets can do all of the things other magnets do. We can use them more easily because they can be turned on and off. Let's see how to make an electromagnet.

You can make a nail into an electromagnet by winding wire around a nail as you see in the picture. Connect only one end of the wire to a dry cell. Now touch the other end to the dry cell. You will have an electromagnet. Never leave both wires connected to a dry cell. Can you tell why?

There are two ways in which you can make an electromagnet stronger. One way is to increase the energy supply in a circuit. This will force more electrons through the circuit.

Try this. Use one dry cell to make an electromagnet, and test it to see how many nails it will pick up. Then connect two dry cells as you see in the picture. How many nails can you pick up now? Put a rubber band around the nails to hold them together.

Try making electromagnets as shown in the pictures below. What differences occur?



Be sure you use insulated wires.

TEACHING SUGGESTIONS
(pp. 159–161)

LESSON: How do we control electricity to do work?

Background: In 1819, the Danish scientist Hans Oersted discovered that when he held a wire carrying an electric current over a compass, the needle was deflected away from the north-seeking position.

In 1820, the French scientist André Ampère found that a coil of wire carrying an electric current had north and south poles, and behaved like a magnet. It was later found that the strength of the electric magnet could be greatly increased by placing a soft iron bar inside the coil. Such a combination is known as an electromagnet. Huge electromagnets are used in industry today, to lift tons of steel.

About 100 years ago, two scientists, Michael Faraday in England, and Joseph Henry in the United States, independently discovered that magnetic fields can produce electricity. They were both familar with Oersted's discovery that electricity can produce magnetism. Faraday discovered that when a wire forming part of a closed circuit is moved up and down in a magnetic field, a current starts to flow in it. This is called electromagnetic induction.

The production of abundant and cheap electric power is based on this discovery.

Learnings to Be Developed:

An electric current can produce a magnetic field.

A magnetic field in motion can produce an electric current.

Developing the Lesson: Introduce the lesson by demonstrating that a magnetic field is produced around a wire carrying an electric current. Punch a small hole in the center of a cardboard square and pass a few feet of stiff wire through the hole. Support the cardboard horizontally on a ringstand. Clamp two feet of the wire to the stand and connect the ends of the wire to the terminals of a dry cell battery. Sprinkle iron filings on the card and tap it gently. Ask children to observe the circular pattern produced by the filings.

Further, show the children that a wire carrying an electric current not only has magnetic properties, but that it has north and south poles. Remove the cardboard and filings. Disconnect the wire from the terminals and wind a length of it around a pencil to make a coil. Remove the pencil and reattach the ends of the wire to the battery terminals. Bring op-

You have just shown how increasing the push on electrons will make your electromagnet stronger. The other way to make it stronger is to put more coils of wire around the nail. First test your electromagnet with only a few coils of wire. See how large a bundle of nails it will pick up. Now try your electromagnet with more coils. It will pick up a larger bundle of nails.

These two pictures show electromagnets. Can you tell which is the electromagnet part of each and what kind of work it does?

Many things that we use in the home to do work have electromagnets in them—electric fans, washing machines, and others. The part that does the work in each of these machines is the motor. There are a number of electromagnets in each motor. The electromagnets make a wheel turn inside the motor. When the wheel turns, it can be made to turn other things.

Each year many fires occur needlessly because houses are not properly wired. Wires either are too thin to carry the flow of current or are not protected by insulation. Wires carrying electric current must be covered with material that will not conduct electricity. Rubber is an insulating material commonly used on wires. When the insulation on a wire is broken, the unprotected wires may cause a fire. Can you tell how?

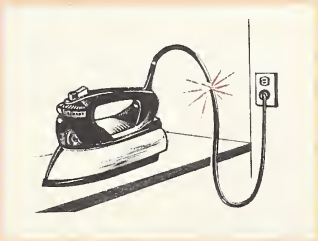
When the insulation around a wire is broken or frayed and the bare wire is touched, there is great danger of injury. Electric current might go through a person's body instead of through the wire. A good rule is never to touch a frayed wire unless the plug is first removed from the wall outlet.

Sometimes electric cords become broken and the bare wires touch each other. When this happens, there is a **short circuit.** Look at the picture below. Can you tell what happens to the electrons moving through the wires when there is a short circuit?

When too many appliances are used on one circuit, the circuit becomes overloaded with moving electrons. The wires become hot. What is the danger when this happens?

On the next two pages you will find rules to follow that will help you to use electricity safely.

What has happened to the wire on the iron below? What might this condition cause? What do you see happening in the picture on the right? How can this be corrected?



posite ends of the coil close to the north pole of a compass, then to the south pole. Ask your pupils to observe the difference in polarity of the opposite ends of the coil.

Ask children if they remember what they learned last year, about the British scientist Michael Faraday. Remind them that he believed it would be possible to produce electricity by passing a magnet through a coil of wire. One day he accidentally dropped a bar magnet into a coil of wire connected to a meter, and saw that the needle of the meter was activated. He thus discovered the basic principle of electromagnetic induction. Let children duplicate Faraday's accidental experiment. Attach a coil of wire to a galvanometer and move a bar magnet in and out of the coil. Note the deflection of the needle on the galvanometer.

Now turn to the activities in the text on constructing an electromagnet as described on page 159.

In discussing the material in this lesson dealing with insulation, give children the opportunity to see for themselves that some materials do conduct electricity, while others do not. Use a variety of objects from the classroom.

TEACHING SUGGESTIONS
(pp. 162–163)

Background: We live in a world of electrical machines and gadgets. Thus, we must learn to use and operate these devices safely. Instilling in your pupils a respect for the dangers of using electricity unwisely will go a long way in their using electricity safely as adults.

The kitchen, the bathroom, and the laundry room are all potential danger spots because they usually have electrical fixtures and equipment in close proximity to water. Electricity and water make a deadly mixture.

In addition to the rules shown in the pictures discuss the following:

1. Don't stand on metal, wet concrete, or wet ground when handling or plugging in an appliance.

2. Don't put pennies or metal foil in a fuse box to replace a blown fuse. Don't use a fuse with higher than the recommended amperage.

3. Don't try to repair your radio or television set. Both of these appliances can give you severe shocks.

4. Don't cover ventilation holes in electrical appliances such as a

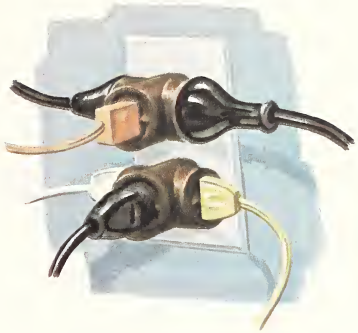
USING ELECTRICITY SAFELY

1. Never touch anything electrical when your hands are wet.

2. Turn off irons, heaters, toasters, and other electrical things when you finish using them.

3. Do not put electrical cords such as lamp cords under rugs or where they can get worn. Remember that insulation around a cord keeps the wires from touching and causing a short circuit.

4. Do not plug too many electrical wires into one outlet. This overloads and heats the wires and can start a fire.



5. Never poke your fingers or any object into electric outlets or sockets.

6. Never touch wires that have fallen down outdoors. Tell a grownup about the wires. He can call the police department and the power company. They will know how to repair the wires.

television set. If you cut off the ventilation, the set may generate enough heat to start a fire.

ADDITIONAL ACTIVITIES:

Make an electrical questioner.

Make a telegraph set.

Show how the telephone operates.

Make a toy motor.

Make a crane that operates with an electromagnet to pick up, carry, and drop iron and steel.

Construct a box containing mysteriously supported objects using hidden electromagnets.

Tell where electricity comes from that is used at home and at school.

Arrange for a trip to a nearby house under construction. Pupils may observe how wiring is done, how various electrical devices are installed, including fuses, switches and insulation, etc.

Ask the school custodian whether he will allow pupils to observe some of the electrical installations in the school building.

Visit a hydroelectric plant.

Examine worn out household electrical appliances.

Find out about Thomas Edison's invention of the electric lamp.

TEACHING SUGGESTIONS
(pp. 164–165)

LESSON: How does a fuse protect an electric circuit?

Learnings to Be Developed:

Electricity is safe to use, if used wisely.

A fuse is an electrical safety valve.

Developing the Lesson: When electrical friction produced by excessive flow causes overheating of wires, a fire could result. The fuse is designed to melt and break the circuit in such cases.

After the children have examined a blown fuse they may be interested in doing an activity that illustrates the principle of the fuse. This can be done by connecting three dry cells, a flashlight bulb in its socket, and a cork, as shown in the diagram. Note that the wires have been bared to allow a short circuit when desired.

The fuse used is a very thin strip of metal foil from a candy bar. The children may need to experiment with different kinds and widths of foil before they find one that will work. The thinner it is, the better.

When a screwdriver is laid across the bare wires a short circuit is caused. This should make the foil fuse blow; if it does, the light will go out.

How Fuses Protect

A **fuse** protects your house from fires by opening the circuit when too many electrons are moving through the circuit. The metal in a fuse melts before the wires get too hot. This action opens a gap that stops the flow of electricity, so that fires cannot start.

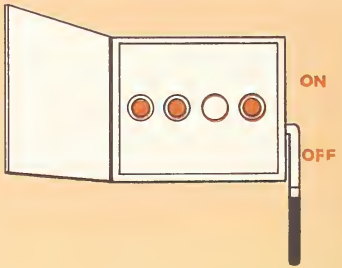
Sometimes people close the circuit by putting a penny in the fuse socket after the fuse blows, instead of using a new fuse. This is dangerous, and no one should ever do it. A penny will not melt easily. The penny allows the electrons to continue moving through a circuit, and the wires may get hot enough to start a fire. Before anyone puts in a new fuse, he should find out what made the old one burn out.

The person who changes a fuse should always open the main switch first, near the fuse box. This shuts off the electric current in the whole house. It is then safe to change the fuse.

Whoever changes the fuse should be sure the new fuse has the same number as the old one had, such as "15A." A fuse that has a larger number should not be used. It should not be used because it will allow too many free electrons to go through the wires of the circuit. If the wires are overloaded, they may become so hot that they will melt and start a fire.

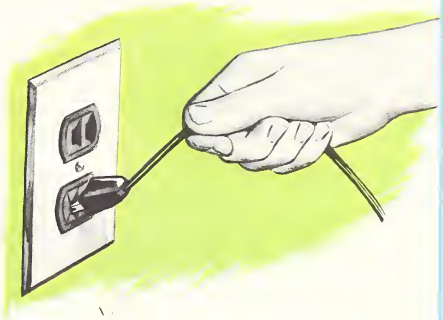
Electricity in your house is safe to use, *if you use it wisely*. But it can be dangerous if you do not know how to use it.

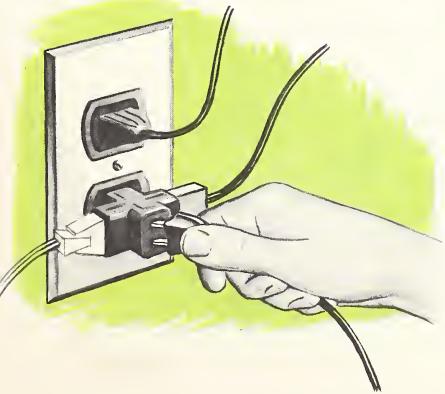
The fuse box in your home may look like the one below, or it may have circuit breakers. If it is like the one below, pull the handle to OFF before replacing the fuse. If you have circuit breakers, switch the breaker back again after finding the cause.

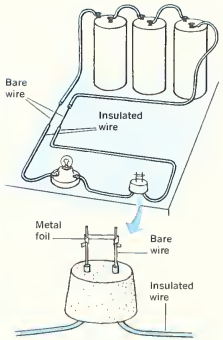


Using What You Have Learned

Look at the pictures below. How many things can you find wrong? Can you tell what safety rules are being broken? How would you correct the things that are wrong?







Background: Following are the answers to *Using What You Have Learned.*

1. The boy should not be working on the radio while it is plugged into an outlet.

2. Never pull an extension cord from an outlet by the wire. Hold the plug securely between the fingers and pull. Very small plugs should be replaced by larger ones.

3. The more appliances plugged into an outlet, the greater the danger of overloading the circuit and causing a fire, or a blown fuse.

4. Frayed cords on appliances invite fire, and danger of shock and possible electrocution. Large power devices such as electric drills should also be grounded.

TEACHING SUGGESTIONS
(pp. 166–167)

Background: These two pages constitute a review of the concepts and terminology introduced in this unit.

What You Have Learned: This is a summary of the entire unit, with new words in boldface type.

Checklist of Science Words: Remind the pupils that there is a *Dictionary of Science Words* on pages 318–325. They should consult this dictionary whenever they are unsure of the precise meaning of a word.

Tell the Difference:

1. Current electricity flows in a conductor, while static electricity builds up on the surface of a substance.
2. A conductor allows the free flow of electricity through it, and an insulator greatly resists such a flow.
3. An open circuit is not a circuit at all because the path is not complete.

WHAT YOU KNOW ABOUT
Using Electricity

What You Have Learned

All **matter** is made up of **atoms.** Atoms are made up of **electrons, protons,** and **neutrons.** Every electron and proton carries a charge of electricity. The electron carries a — or **negative charge** and the proton carries a + or **positive charge.** Charges that are alike push away from each other, and charges that are not alike attract each other.

Static electricity is electricity that is at rest on an object. **Current electricity** is electricity caused by electrons moving through an object.

Materials that allow electricity to move easily through them are called **conductors.** Copper is a good conductor. Materials that do not allow electricity to move easily through them are called **insulators.** Rubber is a good example of an insulator.

The path over which current electricity moves is called a **circuit.** A **closed circuit** is one that begins and ends at a dry cell or other source of electrical energy. There are no openings in a closed circuit. A circuit with an opening in it is called an **open circuit.**

Checklist of Science Words

Here are some science words you read about in this unit. Can you tell what you have learned about each one?

atom	electromagnet	matter
circuit	electron	orbit
conductor	fuse	proton
current electricity	insulator	static electricity

Tell the Difference

Write the numbers 1 to 7 in your notebook. Next to each number, write a sentence that tells how the two things in each question are different.

1. How does static electricity differ from current electricity?
2. How does a conductor differ from an insulator?
3. How does a closed circuit differ from an open circuit?
4. How does a proton differ from an electron?
5. How do like charges differ from unlike charges in their ability to attract each other?
6. How does a parallel circuit differ from a series circuit?
7. How does a 15A fuse differ from a 30A fuse?

Find the Answer

Write the numbers 1 to 10 in your notebook. Next to each number, write the word or words that best fit the description below.

1. Something that makes a good path for electrons.
2. Electricity that is at rest on an object.
3. Everything that fills space.
4. Something that does not allow electrons to move easily from atom to atom.
5. Electricity in which electrons move along a path.
6. What all matter is made of.
7. What happens when bare wires touch each other.
8. The charges that make up an atom.
9. Something that opens a circuit when too many electrons move through the circuit.
10. The charge an electron carries.

4. A proton has a + charge and an electron carries a − charge.
5. Like charges repel and unlike charges attract.
6. In a series circuit there is only one possible path for the electrons to take, while in a parallel circuit many paths are possible for a given electron.
7. A 15A fuse will melt or "blow" before a 30A fuse in the same circuit. Thus a 15A fuse provides more protection because it will open the circuit faster than the 30A fuse when too many electrons are moving through the circuit.

Find the Answer:

1. Conductor
2. Static electricity
3. Matter
4. Insulator
5. Current electricity
6. Atoms
7. A short circuit
8. Positive, negative, and neutral
9. A fuse
10. Negative, or −

TEACHING SUGGESTIONS
(pp. 168–169)

Background: These pages reinforce the concepts presented in the unit by suggesting activities that extend the pupil's ability to apply the learnings derived from the unit.

What Are the Words?

1. Electron
2. Insulator
3. Fuse
4. Current
5. Matter
6. Proton
7. Static
8. Circuit
9. Orbit
10. Atoms

You Can Read: Below is a list of books for your pupils.

All About Electricity, by Ira M. Freeman (Random, 1957). Summary of basic principles, with emphasis on historical discoveries.

Electricity, by Bertha M. Parker and Clifford Holley (Row Peterson). The nature and uses of electricity.

Let's Look Inside Your Home, by Herman Schneider (Scott, 1948). Contains a section on the electrical system in the home.

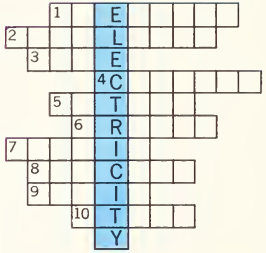
YOU CAN LEARN MORE ABOUT

Using Electricity

What Are the Words?

Write the words in your notebook.

1. The part of the atom that has a – charge.
2. Poor conductor of electricity.
3. Protects your home when electric wires are overloaded or broken.
4. The kind of electricity that lights our houses.
5. Everything that fills space.
6. The part of the atom with a + charge.
7. Electricity which is at rest on an object.
8. A good path for electricity.
9. To circle around something.
10. What all matter is made up of.



You Can Do This

Sprinkle some salt and some pepper on a piece of paper. Ask someone to remove the pepper from the salt—*without touching either one.*

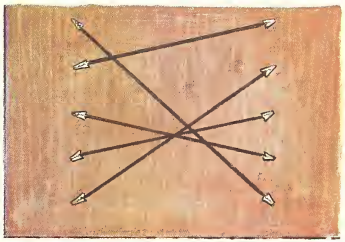
Here is how you do it. Run a comb through your hair a few times. Then hold the comb about an inch above the pepper and salt. Can you explain what happens?

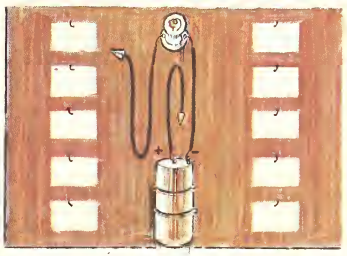
Make an Electrical Questioner

You will need a piece of plywood, 10 cup hooks, 10 pieces of bell wire, 10 alligator clips, a dry cell, and a flashlight bulb.

Screw the cup hooks into the wood in two rows of five each. Remove the insulation from the ends of the wires and attach them to the cup hooks with clips, as you see in picture 1. Attach the dry cell, the bulb, and the wires to the other side of the board, as you see in picture 2.

Hang question cards on the first row of hooks and hang the answer cards on the hook to which you attached the wire. If you clip an "answer" hook to the right "question" hook, the bulb will light.





You Can Read

1. *Experiments with Electricity* by Nelson Beeler and Franklyn Branley. Experiments you can do at home.
2. *The First Book of Electricity* by Sam and Beryl Epstein. What electricity is and what it does.
3. *Picture Book of Electricity* by Jerome S. Meyer. Many experiments with electrical phenomena.
4. *A Boy and A Battery* and *Fun with Electrons* by Raymond F. Yates. Both have many experiments.

Tell how to read an electric meter. Tell how the electric bill is computed. Compute the cost of operation of electric devices in the home.

Your Telephone and How It Works, (Whittlesey, 1952). How sound and electricity make the telephone work.

Below is a list of books for the teacher.

Experience with Magnetism and Electricity, by Gur V. Bruce (Nat'l Science Teachers Ass'n, 1951).

Inside the Atom, by Isaac Asimov (Abelard Schuman, 1956). Information about atoms and uses of atomic energy.

Films:

Elements of Electrical Circuits (11 min., b/w, Encyclopaedia Britannica Films). Illustrates examples of home electrical circuits and a short circuit caused by faulty insulation.

Introduction to Electricity (11 min., b/w & color, Coronet). Practical introduction to current electricity.

Learning about Electrical Current (11 min., b/w, Encyclopaedia Britannica Films). Describes the characteristics, uses, and dangers of electric current.

The Principle of the Generator (11 min., b/w, McGraw-Hill Text Films). Applies the principle of electromagnetic induction to the operation of the generator.

Field Trips for Discovery (14 min., color, McGraw-Hill Text Films).

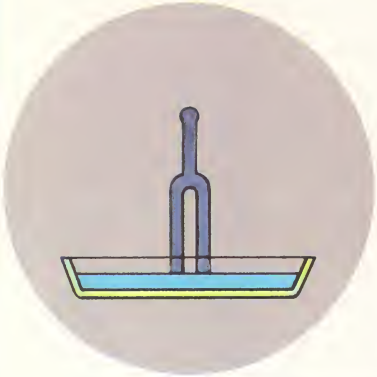
KEY CONCEPTS

Key Concept 1. Events in the natural environment happen in an orderly rather than a haphazard way; man searches for laws to explain this order by observing, hypothesizing, checking his ideas, and rejecting those which do not square with reality.

Key Concept 6. There is a basic tendency toward stability or equilibrium in the universe; thus, energy and matter may be transformed, but the sum total of matter and energy is conserved.

CONCEPTS:

1. Sound is produced by vibrating objects.
2. Sound vibrations travel in matter.
3. Strong sound waves produce loud sounds.
4. The faster an object vibrates, the higher the pitch of its sound.
5. Sound waves are reflected by some materials.
6. Noise can be controlled by preventing the reflection of sound waves.



6

Other concepts appear under "Learnings to Be Developed" in each lesson found in the Teaching Suggestions.

Sound–A Form of Energy

What Is Sound?

What Makes Sounds Different?

Reflected Sound Waves

PROCESSES:

- Observing—Pages 178, 180, 183, 184, 185, 186, 187, 190, 191.
- Experimenting—178, 180, 183, 184, 185, 186, 190, 191.
- Comparing—178, 180, 183, 184, 185, 186, 187, 190, 191, 193.
- Inferring—172, 173, 178, 180, 183, 184, 185, 186, 187, 190, 191.
- Selecting (sources from recall)—182, 193, 197.
- Communicating—195, 196.
- Demonstrating—172, 173, 179, 182, 184, 185, 187, 188, 196.
- Explaining—182, 183, 190, 193.
- Hypothesizing or Speculating—197.

TEACHING SUGGESTIONS
(pp. 172–173)

LESSON: What causes sound?

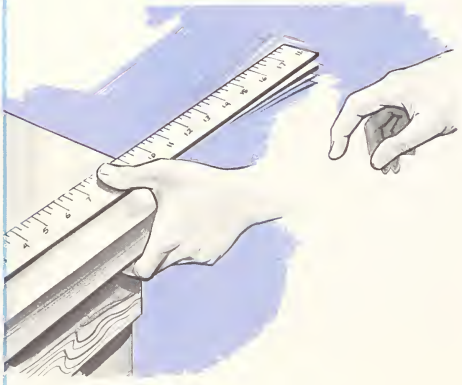
Background: Sound is a form of energy generated in waves by a vibrating body. An important characteristic of a wave is that its energy does not carry with it the medium through which it travels. For example, as a sound wave travels through air, it causes, at the *crest* of the wave, a squeezing together of the air molecules known as *compression*. In the *trough* of the wave it causes a moving apart of the air molecules, *rarefaction*. A sound wave is thus transmitted over distances without causing the air to be carried with it. This is called a compression or longitudinal wave. It must occur often enough, or be repeated *frequently* enough, for us to hear it. The *frequency* then, is the number of times the pressure of the airwave causes our eardrums to vibrate. This mechanical vibration is changed into an electrical impulse in the inner ear, and is then transmitted to the brain.

You have been finding out about energy and the many forms it takes. Are you surprised to find that sound is a form of energy? You know that energy is being used whenever matter is moved. What does this have to do with sound? Can sound energy get work done? In this unit you will find out.

What Is Sound?

Sound is everywhere. You hear all sorts of sounds. Some you find pleasant. Some you find not so pleasant.

What is sound? Here is an old riddle that is often asked when students try to find out what sound is. "If a tree falls in the middle of a great forest, and nobody is near to hear it fall, will there be a sound?" Before you read farther, what do you think is the answer to this riddle?



You might think that sound is something that must be heard. But you will discover that sound does not have to be heard. In fact, there are many sounds that man cannot hear.

In this unit we shall explore the form of energy called sound.

Place a ruler on the top edge of a desk so that about half of it sticks out beyond the desk. Hold down the other half of the ruler firmly on the top of the desk. Flip the free end of the ruler with your finger.

What happens? Do you see the free part of the ruler move up and down? Do you hear anything?

Now try this. Hold one end of a rubber band between your teeth. Hold the other end with one hand. Stretch the rubber band just a little. Now snap it with your free hand.

What do you see, feel, and hear? Do you see the rubber band move back and forth quickly? Do your teeth feel this movement? Do you hear anything?

Does anyone in the school have a drum you can borrow? If so, try this.

What do you feel? What do you hear when you hit the drum top with your fingertips? What reason can you give for the movement of the cereal flakes?

Strike the top of the drum. Put your fingertips lightly on the drum top. Do you feel the drum top move? Do you hear anything?

Sprinkle some dry cereal or any other light but dry material, such as dry sand, on the drum top. Now strike the drum top. Notice how the sand or cereal bounces on it. It moves about because the drum top is moving up and down. What do you hear?

When things move up and down or back and forth, as did the drum top, they are said to **vibrate** (VY-brayt). These movements are called **vibrations.**

Learnings to Be Developed: Sound is produced by vibrating objects.

Developing the Lesson: The use of the exercises suggested in the text provides an excellent starter for this lesson. You can demonstrate the activities with the ruler and the drum, and each pupil can try the exercise with the rubber band. Summarize what these three exercises reveal.

- *What do all three things have in common?* (Moving parts or, more correctly, vibrating parts.)
- *Since sound must reach our bodies* (ears) *in order to be heard, what is vibrating between the drum and our ears?* (Air molecules.)

The text mentions that sound is energy. Have the children review what they learned about energy from earlier units, and attempt to apply these learnings to sound.

TEACHING SUGGESTIONS
(pp. 174–176)

● **LESSON:** Can we hear all vibrations?

Learnings to Be Developed:

Frequency is the number of times per second that an object vibrates.

There are some frequencies we cannot hear.

Frequencies above 20,000 vibrations per second are called ultrasonic.

Developing the Lesson: As an introductory home assignment, ask the pupils to prepare various lists of sounds. For example, a list of sounds heard while lying in bed at night, or while sitting in the kitchen watching mother prepare lunch, might be suggested. In class, have children identify the source of all the sounds they have listed, and describe what is vibrating in each case.

Play some notes, rising on the scale, on a piano or other musical instrument. Indicate that the rise in pitch is in reality a rise in frequency. Most musical instruments have a range of frequency within the auditory spectrum.

As a classroom experiment, direct the children to write down all the

What do you hear as you snap the rubber band?

The ruler vibrated when you flipped it, the rubber band vibrated when you snapped it, and the drum top vibrated when you struck it.

Each time something vibrated, you heard a sound. If you stop the vibration, the sound stops. *Without vibration there can be no sound.*

Is work being done when things vibrate? What is this work? You can feel many objects vibrate, and you can hear the sounds they produce. Sometimes, when big trucks rumble by, you can feel the ground vibrate under your feet.

Sometimes, when you are sitting in a car, you can feel the vibrations of the engine.

When a washing machine or a refrigerator is working, you can hear it. Can you feel it vibrate?

Have you ever put your fingers on the front of your radio when it was playing? What did you feel?

The vibrations of an explosion are very strong. After a big explosion, windows some distance away may be broken by the tremendous vibrations. Can you imagine the vibrations during an earthquake?

Sometimes you can both see and feel the vibrations of an object that is making sound. Sometimes it is not possible. But you can be sure that if you hear a sound, something is vibrating.

Can You Hear All Vibrating Objects?

Now you know that when something is vibrating, it may make a sound. But, can you *always* hear a sound when something vibrates? Now try this activity. Move your finger back and forth as

An earthquake caused much damage to this Alaskan town. Great vibrations were caused by the quake.

quickly as you can. Do you hear a sound? Your finger is vibrating but you hear nothing.

In order for you to hear a sound, something must vibrate between at least 16 times a second and about 20,000 times a second. You cannot wiggle your finger as fast as 16 times or more a second.

You heard a sound when you snapped the rubber band because it vibrated more than 16 times and fewer than 20,000 times in one second.

The number of times an object vibrates in a second is called its **frequency** (FREE-kwen-see). A frequency of twenty-five means that the object is vibrating 25 times a second.

different sounds they hear at a particular moment. After a few minutes, have the pupils close their eyes and note any sounds they have missed before, such as the breathing of a classmate, the rustle of clothes, the hissing of a steam radiator. This may stimulate a discussion of the relative importance of the sense of sight versus the sense of hearing.

You can develop this discussion further by playing a game of sound identification. Place various objects, such as buckets of water, blocks of wood, paper, broom, sheets of cellophane, pots and pans, behind a screen. Select several volunteers to stand behind the screen and perform various tasks such as knocking blocks together, sweeping the broom across the floor, crumpling paper or allowing water to fall on it, crumpling cellophane (used on radio to simulate frying eggs), etc., and ask the class to identify the various activities without seeing them. This is often difficult, because different activities sometimes have similar sounds.

ADDITIONAL ACTIVITIES:

Pupils can learn how a dog's ability to hear sounds of higher frequency than human beings is used in police work, where the policeman uses an ultrasonic whistle to command the dog.

The kind of sound you hear depends on the number of vibrations an object makes. Each sound has its own frequency. If you think back, you will remember that the ruler vibrated at a different frequency than the drum top. You could feel that they were different. And you heard different sounds.

Sometimes an object vibrates so fast that you cannot hear it. If it has a frequency of over 20,000 vibrations per second, you will not hear any sounds. Such very fast vibrations are called **ultrasonic** (ul-truh-SON-ik) vibrations.

A dog can hear ultrasonic vibrations even though you cannot hear them. A dog hears frequencies up to 40,000 vibrations per second. When you blow a special kind of dog whistle, you cannot hear a thing, but your dog will come running. This whistle has a frequency of more than 20,000 vibrations per second, so you cannot hear it.

TEACHING SUGGESTIONS
(pp. 176–177)

Background: Sir Robert Boyle was the 14th child of the Earl of Cork. He was born at Lismore Castle, Munster, Ireland, on January 25, 1627, and died in London on December 30, 1691.

He was a bright, precocious boy and travelled widely through Europe in his early teens with a tutor.

Boyle was a founding member of the Royal Society. He became interested in the characteristics of air and invented a vacuum pump with which he conducted experiments on the property of air. He proved Galileo's theory that in a vacuum all objects fall at the same velocity. Boyle evacuated a column and dropped a feather and a lead weight from the top of the column at the same time. They reached the bottom of the column at the same time.

In his experiments with air, he discovered that air is not only compressible but that this compressibility varies according to the pressure placed upon the air. This relationship is now known as Boyle's law.

Because of his experiments, Boyle concluded that if air is compressible, it must be made up of small, discrete particles.

PATHFINDERS IN SCIENCE

Robert Boyle

(1627–1691) England

Robert Boyle believed that a scientist not only should form hypotheses and do experiments, but should improve those that have already been tested.

Throughout his life, Robert Boyle was curious about the world around him. He found the world full of questions, puzzles, and problems. He believed that there was a pattern in nature. Scientists, he thought, could discover this pattern by experimenting.

One of the many problems that puzzled Boyle was how sound traveled. He

How Sound Travels

Let us suppose that you are in your home and your friend calls to you from the street. You hear the sound, even though there is some distance between you and your friend. How does the sound of his voice reach your ears? The *vibrating objects* are the vocal cords in his throat. As they vibrate, they push back and forth against the air in his throat. This push makes *waves* that travel through the air. You hear the sound when the waves reach your ear.

Vibrating objects have energy. Anything that has energy can do work. What kind of work can your vocal cords do? What matter do they push as they vibrate? The waves that travel through the air are the waves that cause you to hear sound. They are called **sound waves.**

You cannot see sound waves in the air, but you can learn about them.

wondered if air were needed. If a sound were made where there was no air, as in a vacuum, could the sound be heard? Boyle tried to find the answer by doing an experiment.

He hung a loud-ticking watch from the bottom side of a rubber stopper. He placed the stopper with the watch into a glass bottle that was connected to an air pump. The ticking sound of the watch was easily heard. Next, he pumped the air out of the bottle. The ticking became fainter and fainter. Soon no ticking was heard. He knew that the watch was still making sounds because he could see that the watch's hands were still moving.

Now Boyle slowly let air back into the bottle. He began to hear the ticking again. As he let more air in, the ticking became louder and louder. Boyle had shown that sound cannot travel through a vacuum.

His experiment was tested by others to make certain his conclusion was correct. You, too, can test Boyle's experiment. Instead of a watch, use a bell and a bell jar. What happens to the ringing of the bell when the air is pumped out of the jar? From what you have learned, explain why sound travels through gases, liquids, and solids, but not through a vacuum.

Robert Boyle is remembered not only for his many discoveries but also for his brilliance as an experimenter and as a teacher of the experimental method.

TEACHING SUGGESTIONS
(pp. 177–179)

LESSON: How does sound travel through air?

Background: All objects on earth are surrounded by air. Air consists of many small particles, more than 400 billion in every cubic inch.

Air particles, in fact, behave just as though they were small masses of matter connected by springs. Whenever particles near a certain point are closer together than normal, we say that a state of *compression* exists at that point. Whenever particles are further apart than normal, a state of *rarefaction* is said to exist in their vicinity.

A *sound wave* can be described within this framework as something that disturbs, or vibrates, particles of air.

Surface waves on water exhibit some of the characteristic features of sound waves in air. Water waves are vibrations of water particles, much as sound waves are vibrations of air particles. The chief difference between the two is that sound waves vibrate air particles right and left in the direction of wave movement, while water waves vibrate the water particles up and down, at right angles to the direction of wave movement.

The speed at which vibrations move through a medium is called the *velocity* of the wave. Water waves move slowly, only a few miles an hour. Sound waves in air travel much faster, about 1,130 feet a second at sea level, or about 770 miles an hour.

The distance between two successive compressions is called one *wavelength*. A wavelength is also the distance that the wave travels in one cycle of vibration of the air particles. The wavelength decreases as frequency is increased.

Learnings to Be Developed: Sound vibrations travel in air and in water.

Developing the Lesson: Introduce this section by using a toy "slinky" or coil spring, at least 6 inches long in its compressed state. Stretch the spring to a fairly good tension over the top of the desk for about three feet. Gather seven or eight coils at one end and suddenly release them. This gathering (compression) appears to travel the whole length of the spring and then back again. This activity provides a good way for children to visualize what happens to air particles as a sound wave travels through them.

EXPERIMENT

How Do Sound Waves Travel?

What You Will Need

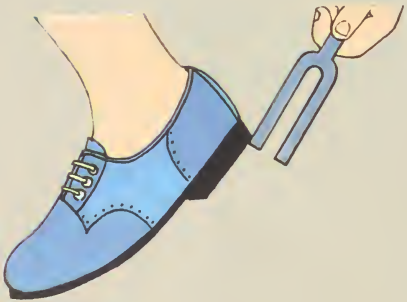
a rubber heel (or another piece of hard rubber)

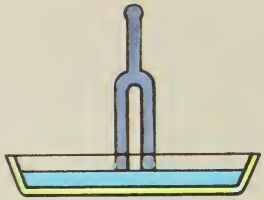
tuning fork

small basin filled with water

How You Can Find Out

1. Strike the tuning fork against the rubber.
2. Hold the fork up to your ear.
3. Touch the top of the water in the basin with the vibrating ends of the fork.





Questions to Think About

1. What did you hear when you held the fork up to your ear?
2. What did you see when you touched the tuning fork to the water?
3. What work is being done here?
4. Where does the energy come from? Remember: Things in motion have energy of motion.

The vibrating fork makes the water vibrate and produces waves that travel out from the fork to the edge of the basin. These waves are like the waves that travel through the air.

When you touched the water with the tuning fork, waves traveled out on all sides from the vibrating fork. Now let's see how sound waves travel in air.

You will need a metal triangle like those used in an orchestra.

One pupil should sit directly underneath the triangle. Another pupil should stand on a chair so that his head is directly above the triangle. Other pupils should stand in a circle around it. Then strike the triangle.

Who heard it? What does this tell you about the direction in which sound waves travel from a vibrating object?

Are there any other things you could use in place of the triangle? Try some other things. See whether you get the same answer.

Do sound waves travel through other things besides air? Do sound waves travel through other things more easily than through air? The next experiment will help you find out.

Will everyone hear the sound? Use the picture to explain your answer.

In the experiment on page 178, the pressure from a vibrating source causes the molecules of the water to be displaced upward and downward with equal force, forming a simple sine curve (the ripples in the water) which will continue as long as energy is supplied. The energy in this case is supplied by the vibrating tuning fork.

Background: Following are the answers to the *Questions to Think About* section on page 178.

1. An unwavering sound of constant pitch.

2. An initial splashing of the water around the tines of the fork will be evidence of vibration. As the fork's vibrations become less strong (amplitude lowers) a pattern of concentric waves will appear which are generated at the tines and move out toward the edge of the dish.

3. Particles of water are being pushed into piles and then relaxing in a constant sequence. The work of moving water is being done.

4. The energy comes from the generating source. Muscular and chemical energy were used to strike the fork and set it in motion. The motion of the tines was kinetic energy.

EXPERIMENT

Do Sound Waves Travel Through Things Other Than Air?

What You Will Need

ruler alarm clock

How You Can Find Out

1. Make the ruler vibrate, as described on page 172.
2. Listen carefully to the sound you hear.
3. Do the same thing again. But this time, press your ear to the desk on which you are holding the ruler. Be sure you vibrate the ruler in the same way each time.
4. Put an alarm clock (or a watch) on the desk. Listen to its tick and then to its alarm.
5. Put your head on the desk and listen again to the tick and to the alarm.
6. Compare the sound of the waves as they travel through air and then as they travel through wood.

Questions to Think About

1. Is the sound louder when sound waves travel through wood? Why?
2. Do you think that sound waves travel better through all solid things than through air? Why?

You can also find out if sound waves travel better through air or through glass. Tap a windowpane. Listen. Tap it again, but this time put your ear against the windowpane.

Make up some experiments to compare how well the sound waves travel from a vibrating object. Try things made of metal. Then try things made of wood.

You will discover that these sound waves travel better through solid things than they do through air. The important thing to remember is that sound waves always travel through *something*—a solid, a liquid, or a gas.

TEACHING SUGGESTIONS
(p. 180)

LESSON: How does sound travel through solids?

Learnings to Be Developed:

Sound travels in liquids and solids.

Particles of matter vibrate and transmit energy from one particle to another.

Developing the Lesson: In the experiment, the vibrations are transferred to a solid material; they are directed, and in a sense concentrated, by the desk. In the air, sound waves move in a continuous spherical pattern away from the source, and our ears receive only a fraction of the total enegry produced by the vibrations. In a solid, we receive a greater quantity of the total vibrations; hence the louder sound.

Background: Following are the answers to *Questions to Think About.*

1. The sound is louder through wood. The energy in transmission is not scattered in all directions, as it is in the air. The solid particles are also closer together.

2. Probably better in solids for the reason given above.

Loud and Soft Sounds

How is a loud sound made? It's easy to find out. All you need are some radish seeds or cereal flakes, and a drum.

Put the seeds or flakes on the top of the drum. Strike the skin of the drum top softly. Watch the seeds bounce. Listen to the sound. Now strike the drum hard. Again look and listen.

Did you see the seeds bounce? Which time did they bounce higher? Which time was the sound louder?

As the drum skin vibrated, it pushed the air above it and made waves in the air. These sound waves pushed through the air in the room. Can you tell why the seeds bounced up and down?

The harder the drum skin was struck, the more strongly the sound waves pushed through the air. The more strongly the sound waves pushed through the air, the louder the sounds.

Now let's compare the sound waves made by loud and soft sounds. You will need a deep pan of water, a small ball or marble, and a larger ball or marble.

Drop the small ball or marble into the pan of water. Watch the waves. Now drop the large ball or marble into the pan. How are the waves different?

Sometimes you cannot hear a sound because the object that is vibrating is causing only very small vibrations. These vibrations cause small, weak sound waves.

A marble is dropped into a pan of water. On the right, a larger marble is dropped into the water. What differences do you see in the waves that are produced?

TEACHING SUGGESTIONS
(pp. 181–182)

LESSON: What accounts for loud and soft sounds?

Learnings to Be Developed:

Strong sound waves produce loud sounds.

Weak sound waves produce soft sounds.

Developing the Lesson: The activity in the text should lead pupils to the conclusion that the generating source of a sound can vary considerably in its vibration. The ensuing sounds depend on whether that vibration was large or small.

Though the size of the sound waves determines loudness, remind children that the molecular structure of the material through which they travel determines speed. Have children look up the speed of sound through various substances.

ADDITIONAL ACTIVITIES:

Pupils can hold a discussion of sound problems in space. Man traveling in outer space cannot communicate except through radio, because of the lack of a medium for sound waves to travel through. There are not enough molecules of air in space for the effective transmission of sound.

This situation will confront our first moon-men too, because the moon has no atmosphere. One of the major adjustment problems of space travel and space lift is to the complete absence of sound.

Background: Following are the answers and additional information on the *Using What You Have Learned* section.

1. Tuning forks can be purchased from all scientific supply houses. A tuning fork with 262 vibrations per second, and one with 524 vibrations per second, can be ordered from Stansi Scientific Company, 1231 N. Honare Street, Chicago, Ill., 60622.

In this investigation the motion of vibration was transmitted by contact from the fork to the ball. Kinetic or moving energy was transferred.

3. The passing of forced air from the lungs acts on these cords in the same way that the air in a toy horn makes a small flap vibrate. The tension of the cords is controlled by muscles.

Teachers may also receive single copies of an excellent book entitled *The Speech Chain: The Physics and Biology of Spoken Language*, from local Bell Telephone Offices.

Using What You Have Learned

1. You can make a ping-pong ball bounce by touching it with a vibrating tuning fork.

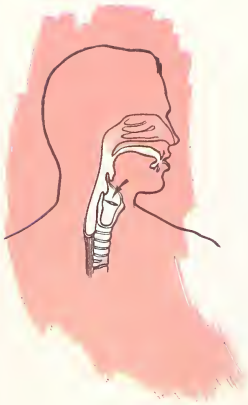
   Glue one end of a piece of string to a ping-pong ball. Put the other end of the string under a book that is on a table. Leave enough string so that the ball hangs down at least two feet from the top of the table. Strike the tuning fork and carefully touch it to the ping-pong ball. What happens? Can you tell why?

2. A bat is an animal that makes sounds we cannot hear. Someone in your class can make a report on how bats use ultrasonic sounds for getting food and for flying around objects in the dark. These books may be helpful:

   Bats by Charles Ripper
   Sounds You Cannot Hear by Eric Windle

3. This is an illustration of the larynx. It is also called the voice box. Your larynx is in your throat.

   Place your hand gently on your larynx. Say your name. Do you feel vibrations? In the larynx are two strong, flat bands called vocal cords. When you speak, these vocal cords vibrate. Can you tell what makes them vibrate?



Look at the bottom half of the picture. Which view do you think shows what happens when you talk? Why do you think so?

What Makes Sounds Different?

Sounds are different in other ways besides being loud or soft. Some sounds are high and squeaky; some are low and deep. The song of a bird is not like the roar of an airplane. The sound of a drum is not like that of a violin. Let's find out now what makes the sounds different.

One important way in which sounds are different is in their **pitch**. Pitch is the word used to describe how high or low a sound is.

Differences in Pitch

What causes differences in pitch? To find the answer to this question, you will need a comb, a small card, and a book covered in cloth.

Hold the edge of a comb with one hand, as shown in the picture. With the other hand, rub the edge of a card slowly over the teeth of the comb. Listen to the sound. Now rub the card over the comb very fast. Listen to the sounds. Which sound was higher? Rub your fingernail slowly over the cover of a cloth-covered book. Then do it quickly. How are these sounds different? Can you tell why?

When you slowly rubbed the edge of the card over the comb, the card vibrated slowly. The sound you heard was low. When you rubbed the card faster, you heard a high sound. The sound was higher because the card was vibrating faster. The same thing happens when you make a rubber band vibrate slower or faster.

The faster an object vibrates, the higher the sound you hear. The slower an object vibrates, the lower the sound.

TEACHING SUGGESTIONS
(pp. 183–185)

● **LESSON:** What differences in sounds are there, besides loudness and softness?

Background: Pitch can be usefully defined as the quality of the sound we hear which is induced by the frequency of the vibrations of the material. The material can be a column of air, as in a wind instrument, or a string attached to a sounding board, as in a piano, or a box containing an enclosed volume of air, as in a violin. There are a number of ways of altering the frequency, and thereby the pitch, of a string. According to the scheme of Mersenne, the French mathematician, the length of a string may be varied to produce a new frequency, its tension may be altered, its weight or thickness may be changed, or all three may be combined. The structure of a piano and the fingering of violin strings are examples of the latter. All will be studied in this lesson and the next one.

Learnings to Be Developed:

The faster an object vibrates, the higher the pitch of its sound.

The slower an object vibrates, the lower the pitch of its sound.

Developing the Lesson: Since pitch is a word usually associated with music, you can discuss it with your pupils in terms of musical instruments. Have the children bring to class as many toy and real instruments as possible. Have them demonstrate how the stringed instruments change pitch, and how the wind instruments change pitch. You might point out, in a simple wind instrument such as a recorder, that changes in pitch are produced when the length of the air column is altered. The air holes alter the length of the air column as they are opened and closed. The principles of changes in pitch on stringed instruments are dealt with quite completely in the text. Before proceeding with the text, however, be sure pupils can relate the term *pitch* to frequency, which is objectively measurable.

We can say this in another way: *The higher the frequency, the higher the pitch; the lower the frequency, the lower the pitch.*

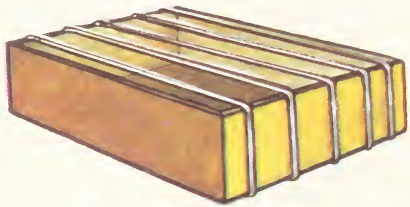
Thickness or Thinness Changes Pitch

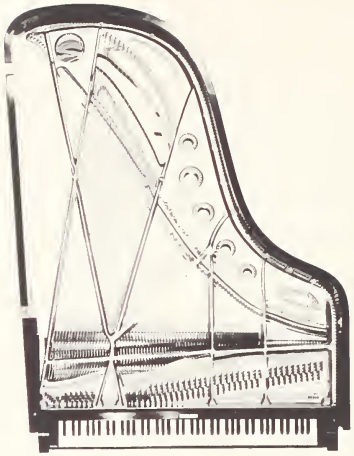
Even the thickness or the thinness of an object changes its pitch. To show this, you will need several rubber bands and an empty wooden chalk box without its lid.

Take several rubber bands of the same lengths, but of different thicknesses. Put them around the empty chalk box. Snap the rubber bands.

Which ones make the lower sounds? Which ones make the higher sounds? Can you tell which one vibrates fastest? Which one vibrates slowest?

Try using rubber bands of the same length and thickness. Then use rubber bands of different lengths but the same thickness. What happens?





Can you tell which side of the piano has the keys to strike for low notes by looking at the strings inside the piano?

A thicker object will vibrate more slowly than a thinner object of the same length and of the same material. A thicker vibrating object makes a lower sound than a thinner one.

If you can open a piano and look at the strings inside, you will see that the strings have different thicknesses.

Strike a low note. You will see a thick string vibrate. Strike a high note. What kind of string will vibrate?

You can see different kinds of strings on a guitar. Perhaps someone can bring a guitar to class.

The tension of a string affects its pitch. Tighter string—faster vibration—higher sound. Looser string—slower vibration—lower sound.

What other instruments can you think of that use different thicknesses to produce different pitches?

You have found out that changing the thickness of a vibrating object is one way to change its pitch. This is because pitch depends on the number of vibrations per second. A thick object will vibrate fewer times in a second than a thin object of the same length. The faster the vibrations, the higher the pitch.

Length Changes Pitch

When you looked at the piano strings, you saw that they were of different thicknesses. You also saw that the strings were different lengths. Does the length of a vibrating object have anything to do with its pitch?

You can find out by changing the length of a vibrating object. You can show this with a rubber band.

Hold one end of the rubber band. Have someone hold the other end and then pull it tight. Snap the middle of the rubber band. Listen to the sound.

Next, hold the same rubber band near its middle. Pull the rubber band as tightly as before and then snap it. Listen to the sound.

Which sound was higher? Which vibrated with a higher frequency—the long rubber band or the short one? When two objects are of the same material and of the same thickness, the shorter one has the higher pitch.

Tightness or Looseness Changes Pitch

So far you have found out that the pitch of an object that vibrates can be changed by its thickness and its length. There is another way to change pitch.

A musician can change the pitch of a stringed instrument. The musician can tighten or loosen each string of his instrument so that each one has the correct pitch.

○ ADDITIONAL ACTIVITIES:

In class, let children make several "guitars." To do this, stretch a rubber band on a flat, 12-inch ruler. Make a bridge of a short pencil stub near one end of the ruler, and secure it with string or a small rubber band. Play by plucking the rubber band near the bridge, and by fingering at the upper end. Be sure the rubber band is thin and tight.

On a 12-inch ruler, with the bridge at the $1\frac{1}{2}$ inch mark, the finger positions of the first few lines of "Three Blind Mice" are as follows: (numbers refer to the inch markings)

8–9–10, 8–9–10, 7–$7\frac{1}{2}$–$7\frac{1}{2}$–8, 7–$7\frac{1}{2}$–$7\frac{1}{2}$–8, 7–$5\frac{1}{2}$–$5\frac{1}{2}$–6–$6\frac{1}{2}$–6–$5\frac{1}{2}$–7–7, 7–$5\frac{1}{2}$–$5\frac{1}{2}$–6–$6\frac{1}{2}$–6–$5\frac{1}{2}$–7–7, etc.

If the guitar is placed on an open cigar box, or a deep dish or bowl, the sounds will be heard more clearly. This is because the vibrations of the rubber band set up vibrations in the enclosed air of the box or bowl and amplify them.

EXPERIMENT

What Does Tightening or Loosening a String Have to Do with Its Pitch?

What You Will Need

rubber band

How You Can Find Out

1. Have someone hold one end of a rubber band while you hold the other end.
2. Snap the rubber band. Listen to the sound.
3. Then, pull it tighter.
4. Snap it again and listen to the sound.

Questions to Think About

1. Which sound was higher?
2. When did the rubber band vibrate faster?
3. Find out how a harp works. How is the pitch changed on a string of the harp?

The tightness of a vibrating object helps determine its pitch. This tightness or looseness is called **tension** (TEN-shun). The tighter a string, the faster it vibrates and the higher the sound it makes: The looser a string, the slower it vibrates and the lower the sound it makes.

Let's review what you have learned about pitch. You have found out that pitch means how high or low a sound is when you hear it. Pitch has to do with the number of vibrations of an object. The faster the vibrations, the higher the pitch you hear. The slower the vibrations, the lower the pitch you hear. To change pitch, the frequency must be changed. This can be done by changing the thickness or the length of the vibrating object. With strings or wires that can be stretched, pitch can also be changed by changing the tension. This is done by tightening or loosening the strings or wires.

TEACHING SUGGESTIONS
(pp. 186–187)

LESSON: How are different sounds produced by a stringed musical instrument?

Learnings to Be Developed:

Tightening or shortening a string raises the pitch.

Loosening or lengthening a string lowers the pitch.

Developing the Lesson: Begin this lesson with the experiment in the text. Let all pupils, working in pairs, perform it. Then discuss the results.

Background: Following are the answers to *Questions to Think About*.

1. The taut rubber band should give the higher pitch. The greater the tension, the higher the pitch.

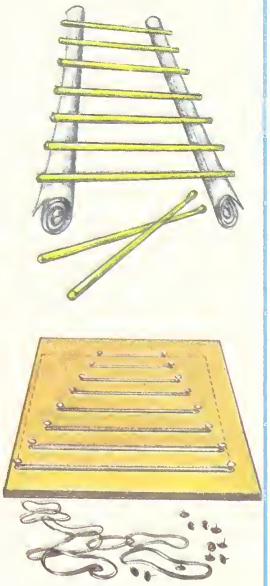
2. The rubber band vibrated faster during the higher pitched sounds. Pupils may not be able to distinguish this too easily unless they slowly loosen the tension while vibrating and observe the difference.

Using What You Have Learned

1. Now that you have learned about pitch, you can build your own musical instruments. One of the instruments you can make is a xylophone. Cut strips of different sizes from a piece of wood that is about an inch thick. You should cut strips that are from 6 inches to 18 inches long. Arrange them on two pieces of rolled-up newspaper as you see in the picture. When you play your xylophone, you will hear that the shorter pieces of wood make higher notes than the longer pieces.

2. Another instrument you can make is a rubber band harp. Put nails into a board as shown in the picture. Stretch rubber bands of different sizes over the nails. Some rubber bands should be thin and others thick; some should be long and others short.

3. Place one end of a ruler on a table. Put one hand on that end to hold the ruler firmly in place. Allow as much of the ruler to hang over the edge as possible. Flip the free end. Then make the part of the ruler hanging over the table much shorter. Flip the ruler again. When do you hear the higher sound? When do you hear the lower sound? Which time did the ruler vibrate more quickly?



Two concepts can be illustrated by using: (1) rubber bands of same size but different tension to produce sounds of different pitch; (2) rubber bands of varying thickness.

3. If the children are not familiar with a harp, you might refer to the picture of the piano string arrangement on page 184, and relate the question to the tuning of a piano. In both cases, pitch is changed by tightening or loosening the strings.

Follow-Up: Return to the stringed musical instruments that have been brought to class. Discuss the "tuning" of these instruments, and establish the fact that this process is one of tightening and loosening the strings, in order to raise or lower the pitch of each note to its proper place in the scale. If any of the pupils play the violin, guitar, or similar instrument, have them demonstrate the tuning process. Point out to the other children that as the tuning pegs are tuned, the strings are actually being made shorter or longer.

TEACHING SUGGESTIONS
(pp. 188–191)

● **LESSON:** Can sound waves be made stronger or weaker?

Background: Interference in sound waves can have several causes. For example, two sound waves, meeting each other in such a way that the rarefied spot of one hits the compressed spot of the other, will cancel each other, producing a much quieter sound, or no sound at all. This happens in the "dead spots" of large rooms or auditoriums.

Or, two waves may meet where the compressed regions of one coincides with the compressed regions of the other, causing the sound to be amplified or made louder.

The most commonly observed interference of sound waves is caused by reflecting materials, and this is the main subject of our lesson. Furthermore, materials that are elastic in nature, such as steel and water surfaces, cause the vibrations or air to bounce off in about the same order in which they impact. This particular kind of reflection gives the effect which we call echo.

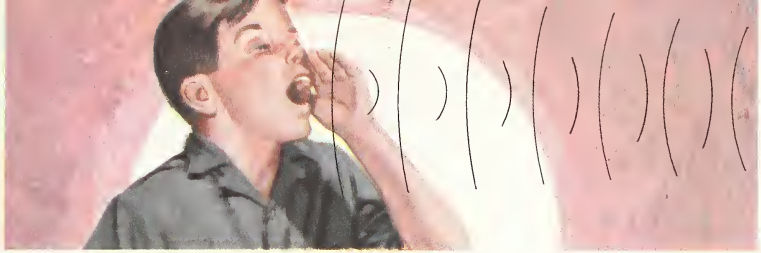
Learnings to Be Developed: Sound waves are reflected by some materials and are absorbed by others.

Reflected Sound Waves

Say a few words. Now put your face near the opening of an empty pail. Say the same words again in the same way.

Is there a difference? Did your voice sound louder the second time? The reason is that the sound waves bounced back from the inside of the pail. The sound waves were **reflected waves.** These reflected sound waves were added to those from your voice. Both kinds of sound waves reached your ear at the same time, so you heard a louder sound with the pail.

Do you like to sing in the bathtub or shower? One reason you may like to sing there is that your voice sounds stronger. The sound waves produced by your vocal cords bounce off the walls of the small room. You hear the waves produced by your vocal cords at the same time that you hear the waves that bounce off the wall. This makes your voice seem louder.



What happens to the sound waves produced by this boy shouting in a tunnel?

You hear both waves at the same time because sound waves travel through the air at a speed of about 1,100 feet a second. It does not matter whether the sound waves are weak or strong. They still travel through the air at this speed. When you sing in the bathtub or shower, the sound waves reach the walls and then bounce back. This happens so quickly that they seem to join perfectly with the sound waves that just came from your vocal cords.

Echoes of Sound Waves

In a large room or auditorium, sound waves have farther to travel before they are reflected. They do not join together quickly with the first sound waves, so the reflected sound is heard *later* than the original sound. When this happens, there is an **echo** (EK-oh). There can be an echo only when the object that reflects the sound is at least 55 feet from the source of the sound. If the distance is less than 55 feet, you will hear the original sound and the reflected sound at the same time.

A flat surface reflects sound better than a rough surface.

Controlling Reflected Sound Waves

Almost everyone has had the fun of shouting in a tunnel. Surely you have heard its great echoing noise. Can you explain what makes this noise?

In a tunnel, an echo can be fun to hear. But sometimes echoes are a nuisance. What can be done to control echoes in auditoriums and theaters, where echoes would make it difficult to hear clearly?

To answer this question, you need to test different kinds of surfaces to find out how they reflect sound.

Developing the Lesson: Bring to class a large seashell (several, if possible) and ask the children if they have ever heard the sound of the surf inside a shell. Pass the shell around and let each child listen to it. Allow some brief discussion of what they heard, and what they think caused it.

Next, pass around an assortment of hollow containers, such as glasses, milk cartons, jars, and cups. Have pupils listen to them in the same way they listened to the seashell. Open the door and windows. Note the rise in the intensity of the "roar" from the containers. Have the class remain absolutely quiet after the door and windows are shut again, and note the drop in the "roar" level. Discuss what the children have heard, establishing the point that all hollow objects can produce the "sound of the surf." Explain how this happens: The reflecting container—shell, glass, or jar—is directing the low level sounds of our surroundings to one small area. The concentration of all these sounds is amplified by the hollow container, producing a

noise that sounds like the roar of the ocean. Pupils' inquiries as to just *how* this happens will lead to the lesson on reflected sound.

During the reading and discussion of the text of this lesson, you might wish to make some further demonstrations.

Have a pupil stand in front of an open window or door, with his back to the class, and say something in his normal tone of voice. Then close the window or door, and have him repeat. Does the class note a difference?

Have the pupils place notebooks behind their ears while you repeat one word in a steady monotone. As they remove the notebooks, have them notice any difference in what they hear. The sound waves reflected off the notebooks will join those coming directly from the source, thus increasing the total number hitting the eardrum, and producing a louder sound.

EXPERIMENT

How Do Different Kinds of Surfaces Reflect Sound?

What You Will Need

empty drinking glass paper towel

How You Can Find Out

1. Hold the rim of an empty drinking glass against your ear.
2. Tap the bottom of the glass gently. Listen to the sound you hear.
3. Now stuff a paper towel into the drinking glass.
4. Tap the bottom again.
5. Listen to the sound you hear.

Questions to Think About

1. Which sound was louder?
2. Can you tell why it was louder?

When the sound waves were reflected from the smooth inside of the empty glass, you heard a loud humming sound. When the sound waves had to travel through layers of the rough paper towel, you heard a softer sound.

The smooth, hard glass surface reflected the sound waves very clearly. But the rough paper towel in the glass did not reflect these sound waves well.

In fact, the towel absorbed the sound waves. A paper towel is **porous** (POR-uss). It contains many air spaces that stop, or absorb, sound waves.

Materials are different in their ability to absorb sound waves. You can test different materials yourself.

First you have to choose the materials you want to test. Some things you might want to use are tissue paper, a pad of writing paper, aluminum foil, and cardboard.

When you have collected all the materials you want to test, get an empty pail. Line the pail with the first material you want to test. Hit the side of the pail and listen to the sound. Change the material and hit the pail again. Listen to the new sound. Test each one of your materials separately in the same way. Which material absorbed the most sound? Which material absorbed the least sound? Which one is the most porous? Which one is the least porous?

You can experiment at home, too. If you have a tiled bathroom, remove all the towels and bath mats. Then

Before you test the materials shown, tell which ones you think absorb sound the best.

Follow-Up: Have children investigate and make reports on the use of sonar in navigation.

○ **ADDITIONAL ACTIVITIES:**

Use a chart of the ear to show how sound waves enter the body. Point out the various parts of the ear, and trace the effects of the sound waves through each part. Discuss how our ears are especially fitted to receive sound waves and to produce the stimuli which activate the brain.

Using a model of the ear and brain, have pupils discuss possible causes of damage through congenital defects, infections, and accidents which would impair hearing. Draw up some rules of hygiene for the ear.

Pupils might report on audiometer tests which give a measure of hearing proficiency, and on medical or surgical treatment designed to overcome hearing deficiencies.

Place the handle of a vibrating tuning fork against the skin behind the ear. Relate this to various types of hearing aids.

TEACHING SUGGESTIONS
(pp. 192–193)

● **LESSON:** How does man control unwanted noises?

Learnings to Be Developed: Noise can be controlled by preventing the reflection of sound waves.

Developing the Lesson: Bring the class to the auditorium and have a pupil read a short selection of material (poem, essay, or science text) while standing about one foot behind the stage curtain. While reading is in progress, have a second child draw the curtain until the reader is visible to the class.

Discuss the properties of the curtain in absorbing sound, rather than reflecting it.

If the auditorium is large, you should detect echoes when only your one class is present.

- *Why aren't echoes noticeable when the room is filled?* (The bodies absorb many sounds.)

Investigate the other sound deadening features of the auditorium, and also its reflecting features.

sing any song you like, and listen to the sounds as you sing. Now put the towels back in place and sing the same song in the same way. Listen to the sound. When did your song sound louder? Why?

Curtains and draperies in rooms and auditoriums are not hung there just for decoration. They are porous, so they absorb sound waves.

Can you explain why rugs on a floor help to keep a room quiet?

Draperies, rugs, and curtains are not always enough to stop or to control all noise. In addition, other porous materials are used to absorb sound waves.

This singer is recording in a special room. What kind of material lines the room? Why?

Cork is one of these porous materials. Because it has thousands of tiny air spaces, it absorbs many of the sound waves. Such materials are often called **soundproofing materials**. They are used to absorb and control noises and echoes.

Look in your school cafeteria, your auditorium, and your gymnasium to see what kinds of walls and ceilings they have. Are they soundproof?

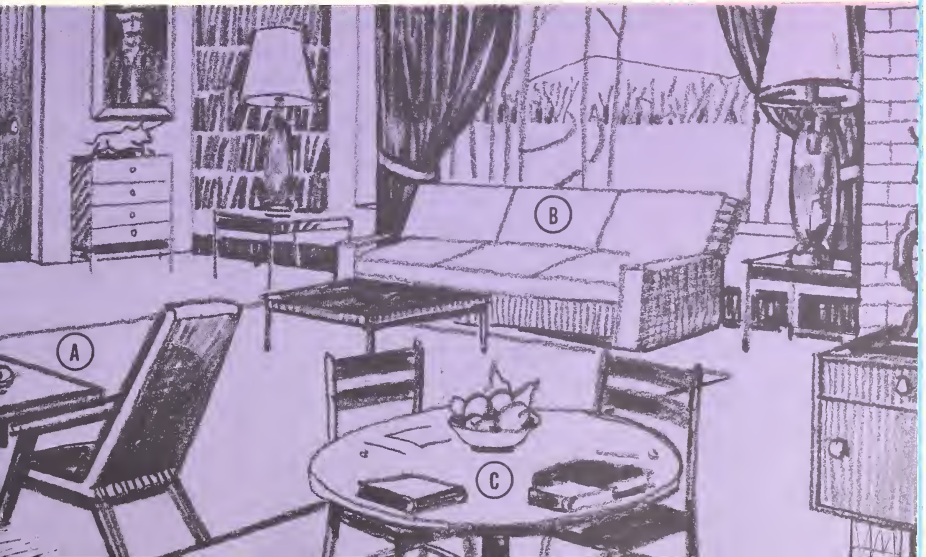
Planning for Noise Control

There are other ways of controlling noise. Schools are often placed away from the street so that street noises do not reach them. Often shrubs and trees are planted to act as sound wave absorbers. Playgrounds are often planned so that their noise does not reach the classrooms.

Look under your chair. Does it have wheels or rubber guards on the legs to prevent scraping noises? Look on the door to your classroom. Has the door a control on it to make it close quietly and slowly? What material is your classroom floor made of? If you are in a modern building, it may have floors of rubber or cork tile, which absorb sound waves.

Using What You Have Learned

1. Knowing the speed of sound helps man learn the depths of water and locate objects under water. Perhaps one of the pupils in your class would like to tell how scientists and engineers do this. He can look up *sonar* in an encyclopedia.
2. Do you think there are any sounds in outer space? What do scientists think about this question? How might you find out?
3. Can you hear things against the wind as well as with the wind? Why?
4. The picture shows a large room. A small group of people wish to have a discussion. Which spot—A, B, or C—would be best? Why?



Background: Here are the answers to *Using What You Have Learned.*

1. You might include radar and loran as similar features of echo location devices that use radio waves rather than sound waves.

2. The lack of a transmitting medium makes sound transmission impossible. Perhaps you could borrow a "Bell in vacuo" apparatus from the high school to demonstrate this. Stansi sells an inexpensive one and an evacuation pump which is adequate for elementary schools. The Welch "Rol-A-Lab" also contains one.

3. The wind tends to carry vibrations of air molecules with it. If the direction is toward you, better hearing is possible. If the wind is away from you and toward the source, hearing is difficult.

4. In general, a small group discussion is best around a circular table as at C. Here each speaker can face all listeners.

TEACHING SUGGESTIONS
(pp. 194–195)

Background: These two pages constitute a review of the concepts and terminology introduced in this unit.

What You Have Learned: This is a summary of the entire unit, with new words in boldface type.

WHAT YOU KNOW ABOUT
Sound—A Form of Energy

What You Have Learned

When you hear a sound, you are actually sensing **vibrations.** Vibrations are made when an object moves back and forth.

Some objects vibrate slowly, some rapidly. The number of times that an object vibrates in a second is called its **frequency.** You can hear a sound only if an object has a frequency that is between 16 vibrations each second and about 20,000 vibrations each second.

When an object vibrates more than 20,000 times each second, it makes an **ultrasonic sound.** You cannot hear ultrasonic sounds.

Pitch is the word used to describe how high or low a sound is when you hear it. Pitch depends on frequency. If a sound has a low frequency, you will hear a low pitch. If a sound has a high frequency, you will hear a high pitch.

Sometimes you can change the pitch of a sound and make it higher. You can do this by changing the thickness, the length, or the **tension** of the vibrating object.

A vibrating object makes the air around it vibrate in the same rhythm. The air vibrates each time the object vibrates. These movements of air are called **sound waves.**

Sound waves travel out in all directions from a vibrating object. When they strike another object, they may be **reflected,** or bounced back. These reflected sound waves are called an **echo.**

Sometimes we like to hear echoes. When we do not want to hear them, we use **soundproofing materials** that are **porous** (filled with holes). These materials absorb the sound waves and thus help to control unwanted noise.

Checklist of Science Words

Here are some science words you read about in this unit. Can you tell what you have learned about each one?

frequency	sound waves	ultrasonic
pitch	tension	vibrations

Find the Answer

Write the numbers 1 to 4 in your notebook. Next to each number, write the word that best answers the question.

1. What describes how high or low a sound is?
2. What do we call the number of times that an object vibrates each second?
3. What makes sound?
4. What do we call sound that we cannot hear?

True or False?

In each sentence below, a word is underlined. This word makes the sentence true or false. Write the numbers 1 to 4 in your notebook. If the sentence is correct, write "true" next to the number in your notebook. If you think the sentence is false, write in your notebook the word that will make the sentence true.

1. A thick object vibrates less in a second than a thin object of the same material.
2. The faster an object vibrates, the lower the pitch.
3. When two piano strings are of the same thickness, the shorter one has a lower pitch.
4. The tighter a string, the higher the pitch.

Checklist of Science Words: Remind the students that there is a *Dictionary of Science Words* on pages 318–325. They should consult this dictionary whenever they are unsure of the precise meaning of a word.

Find the Answer:

1. Pitch
2. Frequency
3. Sound waves or vibrations
4. Ultrasonic

True or False?

1. True
2. Higher
3. Higher
4. True

TEACHING SUGGESTIONS
(pp. 196–197)

Background: These pages reinforce the concepts presented in the unit by suggesting activities that extend the pupil's ability to apply the learnings derived from the unit.

Unscramble the Letters:

1. Soundproofing
2. Frequency
3. Vibrations
4. Pitch
5. Ultrasonic sounds
6. Sound waves

You Can Read: The following books will provide you with background information:

The Reproduction of Sound, by Edward E. David, Jr. (Scientific American, Aug. 1961).

Echoes of Bats and Men, by Donald R. Griffin (Doubleday, 1960).

The Physics of Violins, by Carleen M. Hutchins (Scientific American, 1962).

Science and Music, by Sir James Jeans (Cambridge, 1961).

The Magic of Sound, by L. Kettlekamp (Morrow, 1965).

The World of Mathematics, by James R. Newman, ed. (Simon & Schuster, 1956).

YOU CAN LEARN MORE ABOUT

Sound—A Form of Energy

Unscramble the Letters

1. Materials that absorb and control noises and echoes.
2. The number of times an object vibrates in a second.
3. The up-and-down, or back-and-forth, movements of an object.
4. Describes how low or how high a sound is.
5. Sounds which have such a high frequency that we cannot hear them.
6. The way sound travels through the air.

1. DOPOFOSGNUIRN
2. QUEENFRYC
3. SNAVBITORI
4. TCHIP
5. SLAUTRONIC DONUSS
6. NODSU VESAW

Make Your Own Telephone

You will need two tin cans, two buttons, and several feet of string.

Remove the top end from each can. Be sure that the edges are smooth. Now, punch a hole in the bottom of each can. Put the string through both holes and tie a button to each string end.

Have a friend talk into one of the cans while you hold the other one up to your ear. Pull on the cans just enough to make the string tight. Why can you hear your friend's voice?

Guess the Sound

Have everyone in your class bring in one thing that makes a noise which someone in the class will recognize.

Divide the class into two teams. Blindfold two people (one from each team). Let your teacher make a sound with one of the things that someone has brought into class. The first person to guess what is making the sound gets a point for his team.

Then blindfold another pair and let them try to guess a different sound.

You Can Read

1. *Sound* by Marian E. Baer. Experiments you can do to learn more about sound.
2. *The Story of Sound* by James Geralton. A good book to read to learn more about sound.
3. *The Magic Sound* by Larry Kettlekamp. Another good book about how sound is made.
4. *The First Book of Sound* by David G. Knight. An easy-to-read book on the nature of sound.
5. *Sound and Ultrasonics* by Robert Irving. In this book you will learn how recordings are made.

Waves and the Ear, by John R. Pierce and others (Doubleday, 1961).

These books will help your pupils learn more about sound:

Experiments in Sounds, by Nelson Beeler (Crowell, 1961).

Wonders of Sound, by Rocco Feravolo (Dodd, Mead, 1962).

Films:

Nature of Sound (11 min., color, Coronet). Explains the nature of sound, through everyday examples. Studies the principles of sound's vibration, its characteristics and transmission, and pictures sound on an oscilloscope.

Sounds All About Us (11 min., b/w, Coronet). A boy learns that vibration is the cause of sound, and that sounds differ and can be identified through the characteristics of loudness, pitch, and quality.

What is Sound? (11 min., b/w, McGraw-Hill Text Films). Exposes the nature, source, and transmission of sound waves. Shows that all sound is caused by vibration; demonstrates how sound travels through solids, liquids, and gases; and explains why sounds vary in pitch.

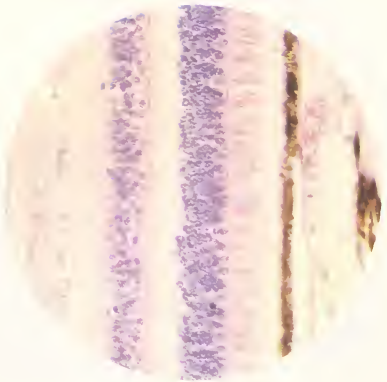
KEY CONCEPTS

Key Concept 1. Events in the natural environment happen in an orderly rather than a haphazard way; man searches for laws to explain this order by observing, hypothesizing, checking his ideas, and rejecting those which do not square with reality.

Key Concept 6. There is a basic tendency toward stability or equilibrium in the universe; thus, energy and matter may be transformed, but the sum total of matter and energy is conserved.

CONCEPTS:

1. Light is a form of energy.
2. We see many objects by the light reflected from them.
3. Materials may transmit, reflect, or absorb light.
4. The eye collects light from objects and projects their images on the retina.
5. Light is bent as it passes from one medium into another.
6. We "see" with our brains.
7. Some defects in vision can be corrected by wearing glasses (lenses).



7

Other concepts appear under "Learnings to Be Developed" in each lesson found in the Teaching Suggestions.

Light and Sight

Light Does Work

How You See

PROCESSES:

- Observing—Pages 200, 203, 204, 207, 217, 220.
- Experimenting—200, 207, 217, 220.
- Comparing—200, 203, 207, 217, 220.
- Inferring—200, 201, 203, 205, 207, 217, 220.
- Selecting (sources from recall)—201, 217, 221.
- Communicating—217, 218, 219, 220.
- Demonstrating—203, 204, 205, 211, 212, 213.
- Explaining—203, 217.

TEACHING SUGGESTIONS
(pp. 200–202)

● **LESSON:** How does light behave when it strikes an object?

Background: Light is the visible segment of a whole spectrum of electromagnetic waves, or radiant energy, that travels through the universe at a uniform speed of about 186,000 miles per second.

Light travels in a straight line, as distinct from sound, for example, which can travel around corners. The direction of light can be changed by mirrors (reflection), or by lenses or other transparent media which are denser than air (refraction).

We see objects only because light is reflected from them to our eyes. If light passes totally through an object, it is "invisible." This is very rare. More usually, enough light is reflected into our eyes to let us know the object is there; we then say that it is transparent. Invisible glass, such as is used in certain shop windows, is curved so that light is reflected downward rather than toward our eyes.

Light is made up of components having different wavelengths. (Wavelength is velocity of light divided by frequency.) Each wave-

Did you know that you see only when the energy of light strikes certain cells in your eyes? Light energy makes it possible for you to see. How much of the world around you would you know about if light did not help you to see? Close your eyes for a few minutes. Then answer the question.

Light Does Work

You have already learned that light is a kind of energy. You also know that energy can do things. What are some things that light energy can do?

When you studied green plants, you found out that the energy of light changes materials to make food. This process is called *photosynthesis*. Such changes are called chemical changes. Sunlight can bring about chemical changes.

Have you noticed how some things change when they are put into the sunlight? You can see what happens by leaving a sheet of dark red paper in the sunlight for several days. Before you put the sheet into the sunlight, cover one half of it with black paper. This will keep sunlight from reaching half the paper. After several days, compare the covered half with the half that received sunlight. How did the sunlight change the paper?

Did you know that sunlight can make changes on the film in a camera? This happens every time you snap the shutter of your camera and then have the film developed into a photograph.

How Does Light Make It Possible to See?

Why can't you see objects in your room at night when the light is turned off? The objects are still there. You still have the same eyes. But when there isn't any light, you cannot see these objects.

How, then, does light make it possible to see?

If you turn on a lamp in a dark room, you will see the lamp. You see it because it is producing light. You

can also see other objects in the lighted room. The other objects are not producing light, but they are lit up. Then where does *their* light come from?

You have learned that light bounces off many objects that it hits. When this happens, we say that light is *reflected* from the object.

How Light Is Reflected

Most objects you see around you have rough surfaces. A rough surface reflects light in many different directions. Blotting paper, raw wood, and dirty glass are among the things that have rough surfaces. When light hits rough surfaces, it is reflected in many directions. Each little place on the rough surface reflects a little light in the direction of your eyes. To you the entire surface seems to be evenly lighted.

Suppose you polish the dirty glass, sand the wood until it is smooth and varnish it, and gloss the paper. You now have smooth surfaces. A smooth surface does not reflect light in many different directions. Look at the diagram to see how light is reflected from a smooth, shiny object.

When light hits a smooth, shiny surface, most of the light is reflected to your eyes. Do you see how the light bounces off the smooth, shiny surface? Often light reflected from a shiny surface will hurt your eyes.

From what you know about reflection, answer these questions:

1. Should schoolbooks be printed on rough or glossy paper?
2. Should the walls of your room be painted with glossy paint?
3. How would you choose the best place for your reading light?

Materials that allow almost all of the light that hits them to pass through easily are **transparent.** How many transparent materials can you name?

Use the pictures below to describe what happens when light hits a rough surface and what happens when light hits a smooth surface. What are the differences?

length has a characteristic color. So-called "white" light is a combination of these. They are separated, so that we see different colors, when they reflect off objects of different colors. A red sweater, for example, absorbs all the wavelengths of visible light, except the red, which it reflects off to the viewer. We know that differences in color are due to the absorption of some light waves and the reflection of others.

Learnings to Be Developed:

Light is a form of energy.

We see many objects by the light reflected from them.

Various materials either transmit, reflect, or absorb light.

Developing the Lesson: Begin the lesson with some "card tricks." Make two holes, about an inch in diameter, in the cover of a shoe box. Place a playing card in the bottom of the box, underneath one of the holes, and close the box. Cover the other hole with another card, and ask a pupil to identify the card in the box by looking through the hole above it.

- *Why can't he?* (Because there is no light in the box.)

Now remove the card which covers the other hole and have him try again.

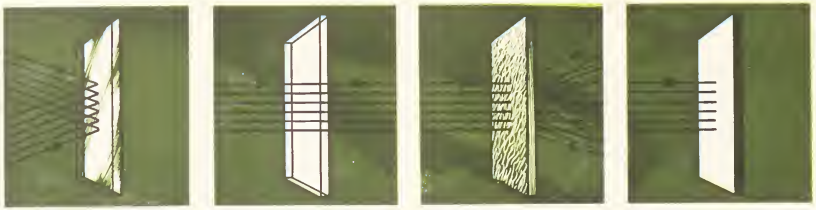
- *Can he see the card now?* (Yes, because light can now enter the box through the open hole, and reflect off the card into the eye of the observer.)

Take three more playing cards and punch a hole in the center of each one. Line them up so that an object behind them can be seen through the holes. Now move the middle card just a little bit out of line.

- *Can the object behind the last card still be seen?* (No.)

Discussion of this experiment will lead to the fact that light travels only in a straight line. Now take a section of flexible tubing, such as a vacuum cleaner hose or garden hose, for viewing. Pupils will not be able to see an object at the other end of the tube unless it is held perfectly straight.

Follow-Up: To demonstrate the concepts of both reflection and absorption, darken the room and place various colored transparent objects between a source of white light (such as a flashlight or a slide projector) and the class. Point out that white light enters the transparent object, but only certain components of that light leave it. The rest are absorbed. Some discussion of why we see color might follow here.



Reflecting | Transparent | Translucent | Opaque

Look at the pictures. What happens when light hits these materials?

Materials through which light cannot pass are called **opaque.** Wood and metal are opaque materials. How many other opaque materials can you name?

If light scatters in all directions on passing through a material, the material is **translucent.** Materials such as frosted glass, tissue paper, and waxed paper are translucent materials. Some light will pass through these materials, but not enough to allow objects to be seen clearly. How many translucent materials can you name?

Light-colored objects reflect most of the light that hits them. Dark-colored objects absorb most of the light that hits them.

Any of three things can happen when light hits an object:

1. It may be reflected.
2. It may pass through the material.
3. It may be absorbed.

All three things usually happen when light hits an object, but in different amounts.

You have learned that when light shines on an object, some of the light is reflected. When this reflected light reaches our eyes, we are able to *see* the object. For us to be able to see an object, it has to reflect some light to our eyes.

Look at different objects in your room. Each object reflects light to your eyes. Where does the light come from?

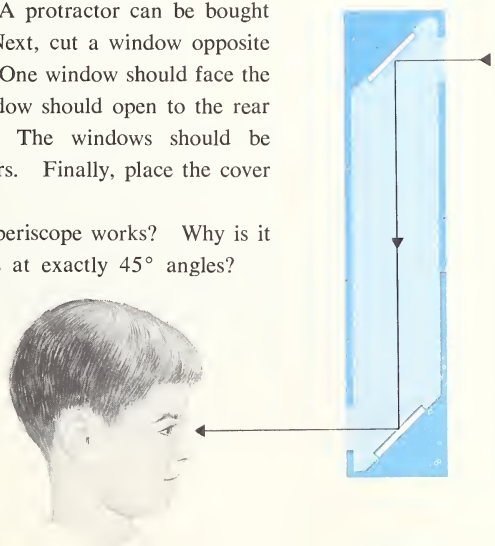
Hold this book at arm's length in front of your eyes. Can you see the objects that are behind the book? Are the objects still reflecting light? Why can't you see them? There are really two ideas that answer the question: (1) light will not go through certain things; (2) light travels in straight lines. How do these ideas answer the question? Keep these ideas in mind as you read about how you see.

Using What You Have Learned

1. Why is a book easier to read when it is printed on a paper with no gloss than when it is printed on shiny paper?
2. Find out how one-way mirrors work.
3. Demonstrate to your class how the reflecting mirror of an automobile headlight works.
4. Next time you enter a darkened room, note whether light-colored objects or dark ones are more easily seen after your eyes are adapted to the semidarkness.
5. From what you know, can you tell why a frosted light bulb produces less glare than a clear bulb?
6. One good way to learn how light is reflected is to build a periscope.

   All you need is a shoe box, two pocket mirrors, and tape. Fasten the mirrors at 45° angles across both ends of the shoe box, as in the picture. To measure and check your angle use a protractor. A protractor can be bought at a five-and-ten-cent store. Next, cut a window opposite the midpoint of each mirror. One window should face the upper mirror. The other window should open to the rear and face the lower mirror. The windows should be slightly smaller than the mirrors. Finally, place the cover on the box.

   Can you explain how the periscope works? Why is it necessary to place the mirrors at exactly 45° angles?



TEACHING SUGGESTIONS
(p. 203)

Background: The following material will provide you with information for the *Using What You Have Learned* section.

1. Too much light is reflected from shiny paper, which may disturb, or even pain, the eye.

2. All glass surfaces reflect, as well as transmit, light. A one-way mirror has one surface treated to reflect more light than it transmits. This is true of most windows at night.

3. The parabolic curve focuses all rays into a beam of approximately parallel rays.

4. Since darker objects absorb more light, light-colored objects will be more easily seen in semidarkness, for they will reflect whatever available light there is.

5. The frosting distributes the light from the source more evenly in all directions.

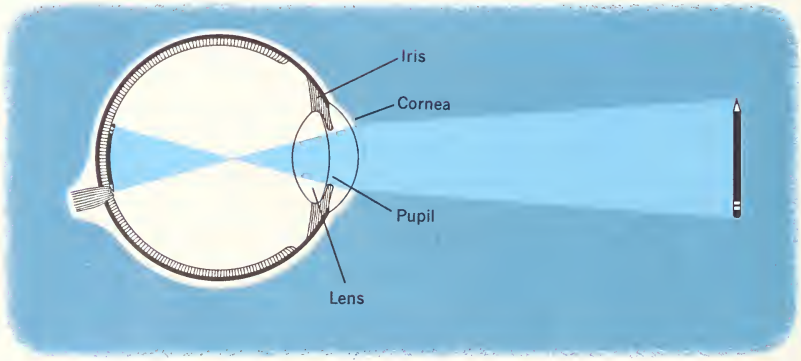
6. The angle at which a light ray strikes an object is the same as the angle at which it is reflected. To make a 90° turn, light must be reflected off at a 45° slope, twice.

Let us trace the path that light takes as it enters your eyes. Light touches many parts of your eye. You cannot see all these parts. But some parts of your eye can be seen simply by looking into a mirror.

Light enters your eye through a clear covering called the **cornea** (KOR-nee-uh). Look at one of your eyes in a mirror. You cannot see the cornea, because it is like a thin sheet of colorless cellophane or glass. Do you see the circle of color? The circle of color is blue, brown, gray, green, or a mixture of two colors. Notice the black circle in the center of the color. This circle is really a space inside your eye. It is called the **pupil**. Light travels through the cornea and then goes through this space.

You may be wondering why the hole looks black. It looks black because the part of the eye behind the pupil is dark. If you make a small hole in a covered box, it will look black, too. This is because the inside of the box is dark. Try it and see.

Look at the circle of color again. The color has nothing to do with how well you see. This ring of color is



See page 202, Book 6, for a model that makes very clear to children why an upside-down image forms on the retina. Reproduce the model on the chalkboard and have children trace the path of each marble.

TEACHING SUGGESTIONS
(pp. 204–206)

● **LESSON:** How does the human eye control light?

Background: In man and other higher animals, the eye is very much like a camera both in structure and operation. Light rays reflected from an object pass through the cornea of the eye, into the *pupil,* and then through a *crystalline lens.* This lens focuses the rays so that an inverted image is formed on the *retina* at the rear of the eyeball. The retina is a membrane composed largely of light-sensitive cells, which contain a material known as *visual purple.* From the retina, the image is transmitted by the optic nerve to the cerebrum, where the brain interprets the inverted image, and turns it right side up.

Learnings to Be Developed: The eye collects light from objects and projects their images on the retina.

Developing the Lesson: The best way to explain the structure of the human eye is with a large biological model. Such a model can be purchased from Wards Natural Science Establishment, P.O. Box 1712, Rochester, New York, or P.O. Box 1749, Monterey, California. If a model is not available,

called the **iris** (EYE-riss). The iris is really a muscle. The iris can make the pupil bigger or smaller. The wider the pupil is opened, the more light can enter the eye. The most light enters your eye when the pupil is opened wide. When would your pupils be opened wide? When would they have the smallest openings?

You can watch your iris as it opens and closes the pupil of your eye. In a dark room, hold a mirror to your face. Now turn on a flashlight or a lamp near you. Watch in the mirror and see how the iris gets larger, making the size of the pupil smaller. This shows you what happens when you go out into the bright sun.

You have probably noticed that when you go from the bright outdoor light into a dimly lit theater, it is very difficult to see. After you are in the theater for a while, you can see much better. Can you explain how this happens? What does the iris of your eye have to do with it?

The light passes through the pupil and strikes the **lens**, which is behind

One picture shows what happens when you enter a brightly lit room. The other shows what happens in a dimly lit room. Which is which?

Use the pictures to identify the parts of the eye—the iris, the pupil, and the cornea.

perhaps the school nurse can provide a chart of the eye for your lesson. Allow the children to examine the model or chart very closely, and discuss its structure and interrelated parts.

Children can see the reaction of the iris in shaping the pupil, by a simple classroom experiment. Divide the class into pairs. Turn off the lights in the room and have one child in each pair close his eyes and cover them with his hands. This lack of light will cause the pupil of the eye to open wide.

Direct the other child in each pair to observe the changes that occur in the iris and pupil of his partner's eyes, when the lights are turned on and the eyes are opened. As the light intensity increases, the pupils attempt to shut out the light by constricting or becoming smaller.

Repeat the experiment with children reversing their tasks.

Discussion of what occurred during the experiment should develop the idea that the action of the iris in closing the pupil when too much light is present is a protective adaptation and prevents damage to the sensitive receptors of the retina.

Follow-Up: Another protective adaptation of the eye is the blinking reflex. Children might demonstrate this also by working in pairs, with one child trying not to blink, while the other gestures toward his face. For safety's sake, it might be better if only one pair of children does this while the rest of the class observes.

Look at your finger and at the lamp. What do you see in focus? What does this tell you about the lens in each of your eyes?

the pupil. The lens in the eye is a little like the lenses in eyeglasses, in magnifying glasses, and in telescopes.

But there is one very important way in which the lens in the eye is different from these other lenses. The lens in the eye can change its own shape. There are muscles in your eyes that change the shape of the lens in each eye. The lenses in both eyes change at the same time. This makes it possible for you to see objects clearly when they are near or when they are far away.

When the lenses are changing their shapes so that you may see an object more clearly, we say that they are **focusing** (FOH-kuss-ing) on the object. When the object appears clearly for you, we say that it is *in focus*.

Hold your finger about six inches in front of your eyes. Now try to look at an object across the room and also at your finger, at the same time. One or the other will be blurred, or out of focus. The lens can change its shape very fast, but it cannot focus on both near and faraway things exactly at the same time. The lens can be only one shape at a time.

How the Lens Works

Lenses that are used for such things as eyeglasses and magnifying glasses are usually curved pieces of glass. As you have learned, light usually travels in a straight line. Light that goes through the lens, as you see on page 216, is bent as it passes into the lens from air. It is bent again when it leaves the lens.

How Does a Lens Bend Light?

What You Will Need

glass, half-filled with water	few drops of milk
2 chalkboard erasers	piece of black paper
	flashlight

How You Can Find Out

1. Put a few drops of milk in a glass half-filled with water.
2. Cut a small hole in a piece of black paper.
3. Now line up the glass of water and the black paper as shown in the picture.
4. Darken the room and make some dust in the air by clapping the chalkboard erasers together near the glass of water.
5. Shine the light from a flashlight through the hole in the paper, as is shown in the picture.

Questions to Think About

1. What do you see when you shine a light behind the hole in the paper?
2. How is the path of light different when you raise the paper?

TEACHING SUGGESTIONS
(p. 207)

● **LESSON:** How does a lens control the light passing through it?

Learnings to Be Developed: Light is bent as it passes from one medium to another.

Developing the Lesson: Follow the steps of the experiment. Discuss the reason for Step #4, creating dust in the air. Since we can see light only when it is reflected from matter, we are increasing the matter (dust) in the air in order to make the beam of light more easily visible.

The substitution of a hand lens for the water glass, should also yield more precise results in this experiment.

Background: Following are the answers to *Questions to Think About.*

1. The beam of the flashlight will be straight as it passes through the hole in the paper on its way to the glass. It will be dispersed somewhat in the water, and will be slightly bent toward the center as it goes through the glass.

2. The path of the light will be bent by the paper before it reaches the glass, which will then bend it further, as described above.

TEACHING SUGGESTIONS
(pp. 208–209)

● **LESSON:** How is light bent?

Background: Since light slows down when passing from air into a denser medium, it also bends when it enters another medium at any angle other than the normal one of 90°. The ratio of bending is sometimes given as a refractive index, the comparison always being with air. Water has a refractive index of 1.3; flint glass an index of 1.7; and diamond an index of 2.4.

The principle of refraction, or bending of light, is the basis of the construction of all optical instruments.

Learnings to Be Developed:

Light travels through air at about 186,000 miles per second.

Light travels at slightly different speeds through different substances.

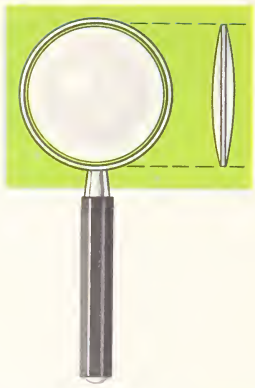
Developing the Lesson: There is no way to demonstrate that the speed of light decreases as the medium through which it is traveling increases in density. Like the rate of the speed of light through air, it is a fact that will simply have to be stated and accepted.

How Light Is Bent

Light travels through the air at a speed of 186,000 miles per second. When light passes through something clear, like glass or water, it is slowed down a little. When a beam of light strikes glass or water at a slant, the part that strikes first slows down first. Since the rest of the beam is still traveling at the same speed, the beam is bent. You can see this happen. Put a pencil in a glass of water.

The pencil looks as though it were broken. The light reflected from the pencil leaves the water at a slant. This happens because a part of the light reaches the air sooner than the rest of the light. It reaches your eye sooner. This makes the pencil look as if it were broken. The light is bent.

Tell why the pencil looks broken.



Is the glass in a magnifying lens flat?

Now you are ready to learn what the lens in your eye does. You will need a magnifying glass and a large piece of white paper. The glass in the magnifying glass looks flat, but it is not. It is thick in the middle and thin at the edges. Its surface is curved. It is a lens, and it will bend light passing through it. Since the magnifying glass is somewhat like the lens in your eye. we will use it to show what the lens in your eye does to light.

Stand across the room from a brightly lit window. Fasten the piece of white paper to the wall opposite the windows in your classroom. Hold the magnifying glass about three inches from the paper. Do you see a bright spot on the paper? Move the magnifying glass toward the paper until the bright spot becomes a picture that shows you clearly the shape of the window, upside down.

When the picture is clear, it is in focus. What did you do to the hand lens to get the picture in focus?

The lens in your eye bends light in almost the same way a magnifying glass bends it. But the lens in your eye does not move forward and backward in order to focus. Instead, the lens focuses when the eye muscles change its shape. The muscles make it more curved to see near objects. And the muscles make it less curved to see far objects.

The lens focuses a picture on the back of your eye. This picture is upside down. If the picture is upside down, how can we see things right side up? The answer is that your brain has learned to turn things so that they appear right side up.

The light passes through the lens of your eye. Next it goes through a colorless liquid that is like watery jelly. This liquid fills the center of the eyeball. Show where it is on page 204. The eye is sometimes called the "eyeball" because it is shaped like a ball.

Finally, the light strikes the very back of the inside of your eyeball. This part of your eye, which the light strikes last, is called the **retina** (RET-ih-nuh). The retina is like the piece of paper you used when you held up the hand lens to focus light coming in through the window.

Children can, however, experience certain aspects of the behavior of light by experimenting with a pencil in a glass of water, as shown on page 208. Supply each child with a glass or clear plastic container, half-filled with water, and a pencil. Have pupils make observations from all possible angles.

When the pencil is viewed through the glass, the part under water seems thicker. When viewed from the top, it all appears to be the same diameter.

There is a varying concentration of water between observer and pencil which acts like a lens, thick at the center and thin at the edge. The view from the top down permits light waves to come to the viewer's eye in a fairly steady stream. There is only a "break" when the interface of water-air is encountered. Have the pupils sight straight down the pencil. No break is noticeable if the pencil is held upright in the glass.

In doing the activity with the paper and the magnifying glass, have as many magnifiers as possible available, so that all children can participate. If you can obtain them, use convex lenses of various sizes and discuss any differences in the images projected.

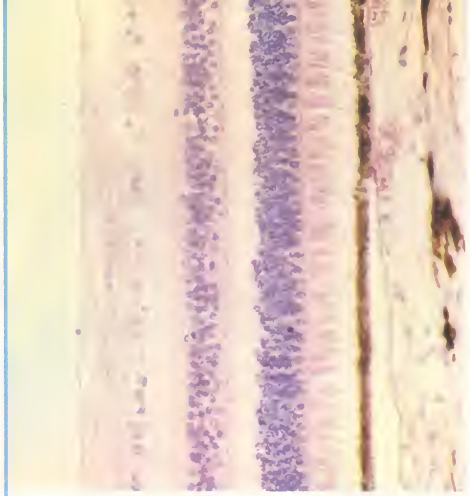
TEACHING SUGGESTIONS
(pp. 210–212)

● **LESSON:** How does the retina react to light?

Background: The cones and rods of the eye respond to light in different ways. The rods are extremely sensitive to the intensity of light and produce sensations of light and darkness. This is called *scotopic vision*. The cones are less sensitive to intensity but more sensitive to colors and are responsible for what is called *photopic vision*.

How is the energy of light transformed into a nerve impulse? Let us assume a photon of light energy enters the eye and strikes a rod cell. The rod contains a protein called *rhodopsin*, or visual purple. When the photon of light strikes the rhodopsin, it causes it to bleach momentarily into a yellow pigment. As a result of this chemical reaction, energy is released which is transmitted to the brain as a nerve impulse.

Essentially the same process occurs in the cone cells but, since the cones are sensitive to colors, this means each cone must contain a special substance that is particularly sensitive to particular wavelengths of light. One group



Which are the cones? Which are the rods? How will you be able to find out?

How the Retina Works

As you will remember, your body is made up of many different kinds of cells. Within the retina are millions of cells. These cells are called **rods** and **cones**, because of their shapes.

The rods and cones receive the light after it travels through the eye. And so the rods and cones are called **light receiver cells**.

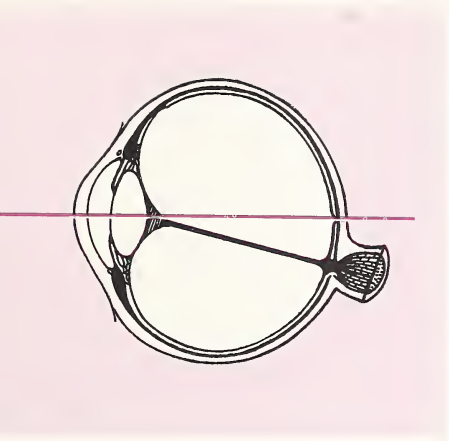
The rods and cones are very, very tiny. In each one of your eyes there are about 120 million rods and about 6 million cones.

You need both rods and cones for seeing. Each has a very special job to do.

The cones make it possible for you to see the difference in the color of things. Without the cones you could not see the difference between the colors of a bright red rose and a green leaf. Cones also allow us to see small shapes and fine lines. Without cones you could not read small print. The cones need a bright light. In dim light they do not work. That is why you cannot make out the colors of things in dim light. It is also why you find it hard to read small print when there isn't a good light.

The rods, on the other hand, work best in dim light. They are the light receivers you use when there is not much light. As nighttime comes, you use the rods more. When it is quite dark, you may see large shapes, but you cannot read the small letters in this book. That is because the cones do not have enough light to do their work.

The rods and the cones are not spread evenly over the retina. In some places there are more cones, and in some places there are more rods.



The fovea is an area on the retina, near the center, directly behind the pupil.

There is one place where there are only cones. It is called the **fovea** (FOH-vee-uh). This is near the center of the retina, in line with the pupil of your eye. Here the cones are packed very tightly together. This is the part of the retina that helps you see small things. It is the part of the retina you use when you read. The fovea is about the size of the period at the end of this sentence. As you read this line, the eyeball moves so that the light bouncing off the letters keeps falling on the fovea of each eye.

You remember that the rods do not help you to see color. They are the light receivers you use when there is not much light. Do you know why you cannot see color well from the corners of your eyes?

Here is something to try. Have a friend pick some brightly colored cards without telling you the colors. Pick one spot straight ahead of you and stare at it. Have your friend hold up a card and tell him to walk slowly around you from behind.

First you will notice that something is moving. You will not know what color it is. Then you will say, "It looks sort of . . ," and all of a sudden you will see that it is bright blue, or yellow, or whatever the color is. The rods will tell you that something is moving. But the color will not be clear until the cones near the center of the eye begin to receive the light from the card. When you see the color clearly, the light is focusing on the fovea.

When light falls on the rods and cones, they are changed in certain ways. These changes are signaled to the brain. The signals are sent through a nerve somewhat as telegraph messages are sent through a wire.

of cones is especially sensitive to wavelengths of red light, another group is sensitive to green light, and a third group is sensitive to violet light. (All three groups are somewhat sensitive to light of other wavelengths; it is only that they are especially sensitive to one particular wavelength.)

When a photon of light energy strikes a cone, the cone will respond strongest only when its particular substance is sensitive to that particular wavelength of light.

Learnings to Be Developed: The retina contains special cells called photoreceptors that are sensitive to light.

Developing the Lesson: The children can perform a series of simple experiments with colored filters that will show them how the eye combines the three basic colors into the complete range of visible colors. Have each child place a green filter in front of one eye. Everything will appear green. Have each child place a red filter in front of the other eye. Everything will appear red through this eye. The conclusion to be drawn is that there are cones in the eye sensitive to red and green colors.

Now have the children look through both filters at the same time—a red filter over one eye and a green filter over the other eye. They will perceive a yellow sensation. This shows the color yellow is a combination of red and green cones transmitting sensations to the brain.

If the same experiment is conducted using green and violet filters instead of red and green, the children will perceive a blue sensation when both filters are used together. The conclusion to be drawn is that the color blue is a combination of green and violet cones transmitting sensations to the brain.

Now, if a yellow filter (which is a combination of red and green) and a blue filter (which is a combination of violet and green) are used as were filters above, white will be perceived. In this way the children can be shown how the eye can see any number of different colors even though it is particularly sensitive to only three.

We actually "see" with our brains. The eye is our equipment for receiving light. It also changes the light into nerve messages that are carried to the brain. If something goes wrong with our light-receiving equipment, we may not be able to see. If something happens to that part of the brain with which we see, then even good eyes will not make it possible for us to see.

Where the nerve that goes to the brain is joined to the eye, there is a spot where there are no rods or cones. Light that falls on this tiny spot sends no messages to the brain. It is called the **blind spot.** You have probably never noticed the blind spot because you have two eyes. When the light falls on the blind spot in one eye, it falls on the rods or cones in the other eye, so you can still see.

You can see for yourself that you have a blind spot. Close your left eye. Hold the cross in the picture below about twelve inches from your face. Look at the cross with your right eye and move the book slowly toward your face. When the book is about ten inches away, the circle on the right will suddenly disappear. The light that is reflected from the circle will be falling on the blind spot.

Some People Need Eyeglasses

Scientists have found out a great deal about how light helps us to see and about how our eyes receive light. Using this knowledge, they can help people who have difficulty seeing.

In order for you to see well, the light that enters the eye must be focused on the retina. In some people, the eyeball is a little too long or a little too short. Then the lens does not focus light correctly onto the retina.

The pictures on the next page show the same view as seen by a person with normal vision, a nearsighted person, a farsighted person, and a person with astigmatism. A nearsighted person sees things that are near better than things far away. A farsighted person sees faraway things better. A person with astigmatism sees *parts* of objects out of focus.

Normal vision

Nearsightedness

WHAT PEOPLE SEE

At the top left is a scene as viewed by a person with normal vision. The other scenes show how people with eye defects see the same scene. What differences do you see?

Farsightedness

Astigmatism

TEACHING SUGGESTIONS
(pp. 213–215)

● **LESSON:** What are some eye defects and how can they be corrected?

Background: In the well-known analogy with a camera, the camera lens is analogous with the *crystalline lens* of the eye, the diaphragm of the camera is analogous with the *iris* of the eye, and the film in the camera is analogous to the *retina* of the eye. This analogy breaks down when one considers how objects are focused upon the film or retina. In a camera, one changes the focus by moving the entire lens assembly forward or backward in its barrel. This changes the distance between the lens and the film. This distance is called the focal length of the lens, and it is measured when the lens is focused upon infinity.

In the eye, the lens cannot be shifted back and forth in this manner, nor is it possible to alter the shape of the eyeball within the eye socket to produce changes in focal length. How, then, does the eye accommodate itself to nearby or distant objects and so bring them into sharp focus?

The crystalline lens is supported by *suspensory ligaments* attached to its outer diameter. The liga-

ments are, in turn, attached to a ring of muscle surrounding the lens. When this muscle is relaxed, it draws away from the lens. This increases the tension upon the ligaments and they pull upon the crystalline lens, which forces it to become thinner. In this way the focal length of the lens is changed. When the ring of muscle tenses, it enables the crystalline lens to assume its relaxed position. It bulges out, which again causes its focal length to change.

When the eye muscle is relaxed, the eye is focused upon infinity; when the muscle is tensed, the eye is focused upon nearby objects. This ability of the lens to change its shape in response to muscular tension or relaxation is called *accommodation*. Accommodation may decrease with increasing age, because of excessive eye strain, or because of an inherited weakness. When the eye cannot accommodate itself to the necessary changes in focus, it becomes nearsighted, farsighted, or astigmatic, according to the particular defect. All three defects can be corrected by glasses, as shown on page 216. Corrective lenses produce sufficient distortion in the opposite direction to the defect to just compensate for the defect. In other words, the eye

Sometimes people are nearsighted or farsighted because the lenses in their eyes no longer change their shape as well as they should. When this happens, the lenses do not focus the light correctly on the retina.

These people are helped by eyeglasses. The lenses of eyeglasses bend

PATHFINDERS IN SCIENCE

Irving Cooper *(1922-)*
Charles Kelman *(1930-)*
Harvey Lincoff *(1920-)*

United States

The retina of the eye is one of the most important parts of the eye. Here, the rod and cone cells are found. Sometimes the retina separates from the eyeball. When this happens, the retina's cells can no longer react to light, and sight is lost. Persons in whom this happens are said to have *detached* retinas.

About thirty-five years ago, **ophthalmic** (ahf-THAL-mik) surgeons (doctors who operate on the eye) discovered that by damaging the retina, they could cause scar tissue to grow. This scar tissue would form a new bond that would hold the detached retina in place. They thought that this method would help save eyesight.

Heat and chemicals were used to wound the retina. This was not an easy operation, and frequently other parts of the eye were damaged. Medical scientists and doctors needed a safer way.

The doctors may have found this way in **cryosurgery** (kry-oh-SER-jer-ee). Cryosurgery means cold surgery. A small, hollow knife, called a probe, is cooled to temperatures many degrees below zero. The probe is cooled with liquid nitrogen. The nitrogen is stored in the handle of the probe and flows to the probe's tip as the surgeon needs it. The surgeon can dial the temperature he needs.

A cold probe is used to freeze lens tissue. Below you see the frozen lens, a ball of ice.

the light before it passes through the lenses of the eyes. In this way, nearsighted and farsighted people can see as well as people who have good eyesight.

Look at the pictures on the next page. Observe how eyeglasses can correct nearsightedness and farsightedness, and how the lenses bend light.

After many experiments on rabbits, in 1962, Dr. Harvey Lincoff, Dr. John McLean, and Dr. Hugo Nano, of New York Hospital, tried cryosurgery on people with detached retinas. The results showed much less damage to the rest of the eye when the cold probe was used.

Today, surgery has this new tool for helping people with detached retinas. Cold surgery experiments are being done to find out if this method can be used for other eye defects and diseases.

No one man is responsible for this scientific discovery. Cryosurgery began when Dr. Irving S. Cooper, of St. Barnabas Hospital in New York, found he could safely put a tiny piece of the brain out of action by freezing it. Cryosurgery worked very well in patients with Parkinson's disease.

Eye surgeons began to wonder whether certain eye operations could be made safer by using cryosurgery. A young eye surgeon, Dr. Charles D. Kelman, experimented to find out if the cold probe could be used to make cataract operations safer.

In cataract, the lens of the eye becomes clouded, and vision becomes poor. The cure is to remove the lens. Glasses are then used in place of the lens. In the operation, the surgeon must pull the lens away from the parts of the eye that hold it in place. Sometimes one of the other parts is damaged in the operation.

Dr. Kelman found that the cold probe caused the lens tissue to freeze into a ball of ice. When he pulled at the ball of ice, the pull was spread across a large area of the lens only—and did not harm any of the other eye tissues. This made a big difference. Dr. Kelman says that pulling a lens with forceps can lead to damage, but pulling a ball of ice is easier and helps to make a clean break.

After the successes of Dr. Cooper and Dr. Kelman, Dr. Lincoff and his associates also decided to experiment with cryosurgery. It was only after many experiments with animals that cryosurgery was used on human patients.

The use of a cold probe in eye surgery is just another example of how scientists build upon one another's work. Today's scientists build on the work of all those who went before them.

and the corrective lens together form a unit whereby the crystalline lens will focus upon infinity.

Learnings to Be Developed: Some defects in vision can be corrected by wearing glasses.

Developing the Lesson: The class discussion can proceed along the lines developed in the background information.

The class can discover what the different kinds of defects look like by looking through sample corrective lenses provided by a local optometrist. By holding the corrective lenses at varying distances from the eye and focusing them upon near and far objects, they can see how the world appears to those with nearsighted or farsighted vision, or with astigmatism.

○ **ADDITIONAL ACTIVITIES:**

Arrange for the nurse to give eye examinations at this time, followed by a nurse-teacher lesson on care of the eyes and prevention of eye disorders.

Conduct a poster contest on good eye habits. Subjects might include: Never use an unshaded lamp. Never sit facing a strong light. Prevent window glare with shades and curtains. Avoid shadows on your work. Avoid sharp contrasts between your work and its background.

TEACHING SUGGESTIONS
(pp. 216–217)

Background: Following are the answers to *Using What You Have Learned,* page 217.

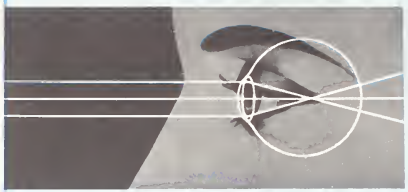
1. The light rays from the penny to the surface of the water travel in a straight line. When these rays reach the air, they are refracted, or bent, over the lip of the bowl and to your eyes.

2. *Optometrist:* One skilled in the testing of eyes and fitting of eyeglasses, and legally authorized to do both.

Oculist: A specialist in diseases of the eye. A medical doctor who is skilled in the examination and treatment of eye diseases and defects.

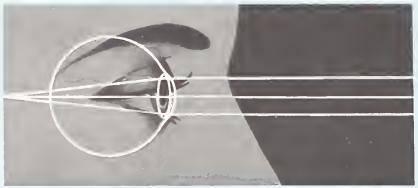
Optician: One who makes or sells glasses and optical instruments.

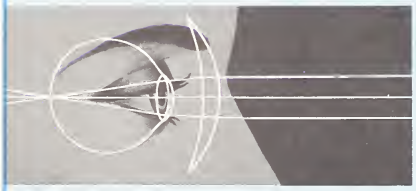
Ophthalmologist: An older term for oculist, above.



In a nearsighted person's eyes, the rays of light focus before reaching the retina. That is why the person sees near things better than he sees things far away. Below you see how eyeglasses correct this condition by making the rays of light focus on the retina.

CORRECTING POOR VISION





Above you see that a farsighted person's eyes focus the rays of light beyond the retina. That is why the person sees things that are far away better than he sees things that are near. Eyeglasses correct this condition by making the rays of light focus on the retina.

Using What You Have Learned

1. If you remember what happened to the pencil when you put it into water, you will be able to explain what happens in this experiment.

   Put a penny into a glass bowl of water. Make sure the penny is near the edge of the bowl. Starting from a place where you can see the penny, take steps backward until you get to a place where you can no longer see it. Now ask one of your classmates to pour water slowly into the bowl, making sure that the penny does not move. You will be able to see the penny again. Can you tell why?

2. You can find out about all the different kinds of jobs that have to do with the eye. Look up these words and then tell what each person does:

   optometrist (op-TOM-uh-trist)
   oculist (OK-yoo-list)
   optician (op-TISH-un)
   ophthalmologist (of-thal-MOL-uh-jist)

3. Form a committee and find out about seeing-eye dogs. Report to the class. Perhaps a blind person would be willing to bring his dog to your school and tell your class about him.

4. Explain how each of the following things is related to your eyesight and to automobile safety: (a) high and low beams, (b) blinking direction signals, (c) the distance a driver can see ahead at night, (d) special colors in taillights, (e) driving in fog, (f) the use of mirrors, (g) glasses for eye defects, and (h) colored glasses.

4. a) High intensity beams of light directed at the eye temporarily cause a loss of image vision and could cause accidents while driving. Low beams should be used when there is oncoming traffic.

b) A blinking light is a distraction. Used for indicating the intention to turn, it attracts the attention of other motorists who can then prepare for this action.

c) This should be a limiting factor concerning the driver's speed.

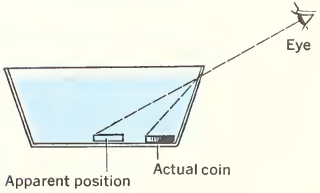
d) They indicate that a car ahead is either stopped, or proceeding in the same direction.

e) Special fog lights and reduced speed are required for safety.

f) To be aware of rear and side traffic.

g) To improve image formation.

h) To cut down the sun's glare in moving traffic, and improve image formation.



TEACHING SUGGESTIONS
(pp. 218–219)

Background: These two pages constitute a review of the concepts and terminology introduced in this unit.

What You Have Learned: This is a summary of the entire unit, with new words in boldface type.

Checklist of Science Words: Remind the pupils that there is a *Dictionary of Science Words* on pages 318–325. They should consult this dictionary whenever they are unsure of the precise meaning of a word.

WHAT YOU KNOW ABOUT
Light and Sight

What You Have Learned

Light is a form of energy. Light makes it possible for you to see. You see objects only when light is reflected from them to your eyes.

Light enters the eye through the **cornea.** It goes through the **pupil.** Around the pupil is the **iris,** which controls the size of the pupil. The light goes through the pupil and strikes the **lens.** The lens **focuses** the light on the **retina.** Within the retina are millions of cells called **rods** and **cones.** They are called the **light receiver cells.** The cones help you to see small things, as well as the differference in colors. The rods work best when there is dim light.

For some people, light does not focus correctly on the retina because the eyeball is a little too long or a little too short. Eyeglasses may help these people to see as well as people who have good eyesight.

Objects may be **transparent, opaque,** or **translucent,** depending on the amount of light that can pass through them.

Checklist of Science Words

Here are some science words you read about in this unit. Can you tell what you have learned about each one?

blind spot	iris	retina
cones	lens	rods
cornea	opaque	translucent
fovea	pupil	transparent

Which Is Which?

Below are two pictures. One picture shows how a nearsighted person sees things. The other picture shows how a farsighted person sees things. Can you tell which is which?

Fill in the Answer

Write the numbers 1 to 5 in your notebook. Next to each number, write the answer that best completes the sentence.

1. The rods and cones are called the ___?___ ___?___ cells.
2. The place where there are no rods or cones is called the ___?___ ___?___.
3. The ___?___ cells make it possible to see the color of things.
4. The fovea is the one place in the retina where there are only ___?___.
5. The ___?___ cells work best in dim light.

Which Is Which? The picture on the left shows how a nearsighted person sees; the picture on the right shows how a farsighted person sees.

Fill in the Answer:

1. light receiver
2. blind spot
3. cone
4. cones
5. rod

TEACHING SUGGESTIONS
(pp. 220–221)

Background: These pages reinforce the concepts presented in the unit by suggesting activities that extend the pupil's ability to apply the learnings derived from the unit.

Unscramble the Words:

1. Iris
2. Pupil
3. Cornea
4. Blind spot
5. Rods
6. Lens
7. Retina
8. Fovea
9. Cones

You Can Do This:

This activity shows how the brain combines the separate images received from each eye into one combined image. The basic reason for this combination of images is that the optic nerve from each eye carries impulses to both hemispheres of the brain. The brain then combines these images to produce the illusion of a hole in the hand.

You Can Read: Additional reading for teacher and pupils follows.

Prisms and Lenses, by Jerome S. Meyer (World, 1959).

Shadows, by Irving and Ruth Adler (John Day, 1961).

YOU CAN LEARN MORE ABOUT
Light and Sight

Unscramble the Words

1. The ring of color that is a muscle.
2. Light goes through this hole.
3. Clear covering of the eye.
4. There are no rods or cones here.
5. They make it possible to see in dim light.
6. This focuses as you look at things.
7. This is like a screen on which the lens focuses the light.
8. There are no rods here.
9. They make it possible to see color.

1. SIIR
2. PILPU
3. ANORCE
4. DIBLN OTSP
5. SDOR
6. SELN
7. NETIRA
8. EVOFA
9. SOCEN

You Can Do This

Roll up a sheet of paper into a tube that is about one inch round. Hold the tube up to your left eye. Now hold your right hand next to the tube about eight inches away from your eye. Look through the tube with your left eye, and at the same time look at your hand with your right eye.

Do you see a hole in your hand? Do you know why?

You Can Make a Model of the Eye

You will need a rubber ball, some cardboard or a piece of wood, and paint of different colors.

Cut the rubber ball in half and paste it onto the cardboard. With your paints, paint on the different parts of the eye. After you have painted on the iris and the pupil, take clear cellophane and put it over the eye. This will stand for the cornea. Now think of some materials for eyelashes and eyebrows.

You Can Read

1. *Experiments in Optical Illusion* by N. Beeler and F. Branley. Many experiments with optical illusions.
2. *Wonders of Your Senses* by Margaret Cosgrove. Vision is one of the senses you will read about.
3. *Our Wonderful Eyes* by John Perry. Tells how we see and how to care for our eyes.
4. *The Wonder of Light* by Hy Ruchlis. Tells how light acts.
5. *The Story of Eyes* by S. Sutton-Vane. A more difficult book for those who want to find out more.

You and Your Shadow, by Bill Severn (McKay, 1961).

Experiments with Light, by Nelson F. Beeler and Franklyn M. Branley (Crowell, 1958).

Color in your Life, by Irving Adler (John Day, 1962).

Sight, A Handbook for Laymen, by Roy O. Scholz, M.D. (Doubleday, 1960).

Lens Magic, by Frances Rogers (Lippincott, 1957).

Electromagnetic Waves, by Robert Irving (Knopf, 1960).

Films:

Demonstrations with Light (12 min., color, Moody Institute of Science). Specially designed lab equipment is used to illustrate the various theories of light—nature, speed, means of propagation. Persistence of vision illustrated and explained; good motivation for physical sciences. Should *raise* questions concerning light as a medium for sound transmission.

Nature of Light (11 min., b/w, Coronet). Light studied as a form of radiant energy; reflection and refraction in optics.

The Science of Light (11 min., color, Churchill Films). By means of thought provoking experiments, a number of properties of light and the concept of how we see are introduced.

KEY CONCEPTS

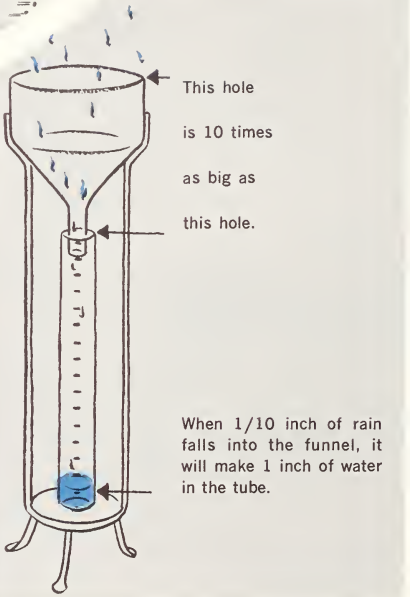
Key Concept 1. Events in the natural environment happen in an orderly rather than a haphazard way; man searches for laws to explain this order by observing, hypothesizing, checking his ideas, and rejecting those which do not square with reality.

Key Concept 2. Lawful change is characteristic of events in the natural environment; although living things tend to produce living things like themselves, over millions of years the earth and living things on the earth have changed, and diversified forms of life have evolved.

Key Concept 3. To find order in the natural environment, the scientist seeks basic units which can be put together in an almost infinite variety of ways; the cell and the atom are examples of such units.

Key Concept 4. All objects in the universe and all particles of matter are constantly in motion; man has discovered and stated the laws governing their motion.

Key Concept 5. The motion of particles helps to explain such phenomena as heat, light, electricity, magnetism, and chemical change.



8

Other concepts appear under "Learnings to Be Developed" in each lesson found in the Teaching Suggestions.

Weather in Your Life

What Is the Weather Going to Be Like?

How Air Acts

Key Concept 9. The scientist has developed measures of space, time, and matter so that he can communicate explanations that are reproducible and make predictions about events in the natural environment.

CONCEPTS:

1. In forecasting weather, it is necessary to know about temperature of the air, air pressure, and water vapor in the air since these determine the weather.
2. Molecules of air occupy space and have weight.
3. As molecules of air and water are heated, their movement increases, and they occupy more space. When they are cooled, the reverse happens.

PROCESSES:

- Observing—Pages 225, 230, 231, 232, 234, 235, 236, 237, 238, 240, 242, 244, 246, 250, 251, 252, 255, 256.
- Experimenting—230, 231, 234, 235, 237, 242, 246.
- Comparing—230, 231, 232, 234, 235, 237, 238, 242, 246, 250, 252, 255, 256.
- Measuring—224, 231, 234, 235, 237, 239, 241, 242, 244, 246, 251.
- Demonstrating—230, 231, 234, 235, 237, 241, 242, 248, 255, 256.
- Explaining—230, 231, 232, 234, 235, 236, 237, 238, 242, 249, 250, 252, 255, 256.

TEACHING SUGGESTIONS
(pp. 224–227)

● **LESSON:** What needs to be done before a weather forecast can be made?

Background: The sun is the source of almost all the energy on the earth and in the atmosphere. The climate and weather conditions of any given place on the globe are directly related to the effectiveness of the sunshine at that particular spot. Winds, air masses, ocean currents, and moisture all depend on solar energy for their movements. The interchange or dynamic balance of heat and moisture over the surface of the earth is studied as a branch of atmospheric science or *meteorology*. Meteorology enables us to make predictions about weather.

In this lesson the emphasis should be on the necessity for keeping track of yesterday's and today's weather conditions, in order to predict tomorrow's. Record keeping is the most important ingredient for reliable forecasting.

This lesson offers an ideal extension of the concepts dealt with in Unit 1—*Comparing Things*. As much as possible, draw comparisons here, of temperatures, pressures, wind directions, and moisture content.

The news reporter says, "Coming up in a minute, the weather forecast for today." And people in every part of the country stay tuned to their radio or television sets to learn what the weather is going to be like. After the forecast is over, many people will plan their day according to the weather forecast

What Is the Weather Going to Be Like?

You have probably looked up at the sky the night before a picnic and said, "It looks cloudy. I think it is going to rain tomorrow." Or, perhaps while playing, you suddenly noticed that it was getting dark and the air was becoming very still. Then you said, "We'd better run for cover. It's going to rain any minute." Five minutes later the rain came. You had correctly **forecast** the weather. When you forecast the weather, you try to tell what the weather will be like sometime in the future.

You probably have correctly forecast the weather many times, but only for a day or so ahead. Could you forecast the weather for next week or next month? No, because there is more to weather forecasting than simply looking up at the sky and making a guess.

Weather forecasting is now done by weather scientists working in **weather stations**. If you were to visit a weather station, you would find the weather scientists using maps and charts and all kinds of special instruments—such as a **rain gauge** for finding the amount of rainfall. The scientists even use balloons of all sizes. Being a good weatherman is a difficult job. Let's find out more about the weather scientist and what he does.

Studying the Weather

The weather scientist has found that when there is a change in the **temperature** of the air, the pressure of the air, and the amount of water in the air, we will get different kinds of weather. Water that is in the air is called **water vapor**. Water vapor is made of very

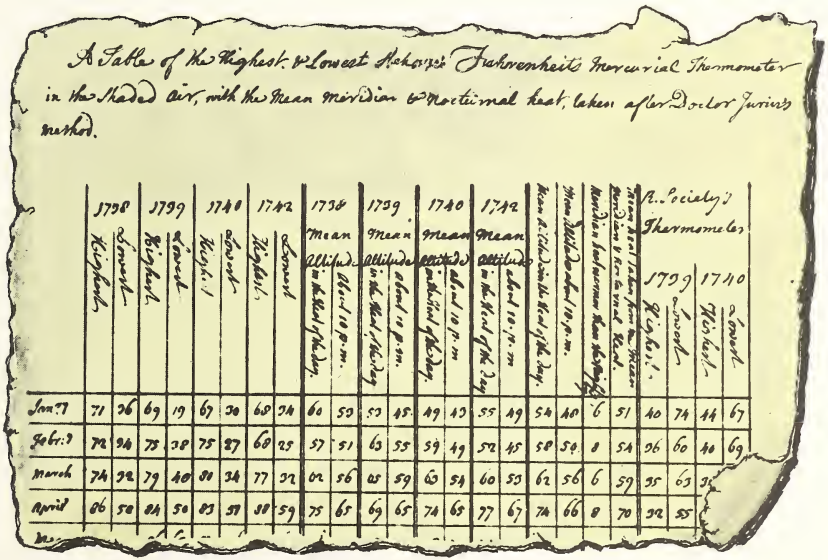
small particles. You cannot see water vapor in the air.

For many years, weather scientists have been keeping records of air temperature, **air pressure**, and water vapor at different times each day. They have also kept records of the kind of weather made by the different conditions. These records help weather scientists to compare weather conditions. The records help them to make better forecasts. However, weather scientists still have a great deal to learn about the weather.

Early History of Weather Forecasting

A little over 200 years ago, in 1753, Dr. John Lining, of Charleston, South Carolina, started using scientific instruments to observe the weather. Every day at 6:30 in the morning, 3:00 in the afternoon, and 10:00 at night, he measured rainfall and wrote down the air temperature, the air pressure, and the amount of water vapor in the air. He studied the direction and speed of the wind. His records were continued for

One of Dr. John Lining's original records is shown below. Can you read some of the weather observations he made over 200 years ago? Can you find out more about him?


A Table of the Highest & Lowest Reaumur's Fahrenheit's Mercurial Thermometer in the Shaded air, with the Mean meridian & Nocturnal heat, taken after Doctor Jurin's method.

	1738 Highest	Lowest	1739 Highest	Lowest	1740 Highest	Lowest	1742 Highest	Lowest	1738 Mean altitude in the Shade (Noon)	Mean altitude in the Shade 10 p.m.	1739 Mean altitude in the Shade 10 p.m.	Mean altitude in the Shade 10 p.m.	1740 Mean altitude in the Shade 10 p.m.	Mean altitude in the Shade 10 p.m.	1742 Mean altitude in the Shade 10 p.m.	Mean altitude in the Shade 10 p.m.	Mean R. Heat in the Shade 10 p.m.	Mean Meridian Heat in the Sun	Mean Nocturnal Heat 10 p.m.	Mean Meridian between Noon & 10 p.m.	Mean Nocturnal Heat between Noon & 10 p.m.	R. Society's Thermometer 1739 Highest	Lowest	1740 Highest	Lowest
Jan.y	71	36	69	19	67	30	68	34	60	50	53	45	49	43	55	49	54	40	6	51	40	74	44	67
Febr.y	72	34	75	38	75	37	60	25	57	51	63	55	59	49	52	45	58	54	8	54	36	60	40	69
march	74	32	79	40	81	34	77	32	62	56	65	59	63	54	60	53	62	56	6	59	35	63	31	
April	86	50	84	50	83	51	80	59	75	65	69	65	74	65	77	67	74	66	8	70	32	55		
May																								

The brief history of scientific weather forecasting shows a gradual increase in scientists' concerns for more detailed and complete information about weather, to allow for more accurate predictions.

Learnings to Be Developed:

In forecasting weather, it is necessary to know about temperature of the air, air pressure, and water vapor in the air since these determine what the weather will be.

Over the years, improved methods of forecasting weather have been developed.

Accurate weather forecasting depends on accurate record keeping and comparisons.

Developing the Lesson: Introduce the topic with a series of questions aimed at stimulating an interest in the importance of record keeping. Summarize the answers.

What was the weather like yesterday?

What is the weather like today?

Answers should include observations regarding temperature, such as warm. or cold, references to clouds or their absence, references to wind, references to humidity or dampness, etc.

What will tomorrow's weather be like?

There may be considerable disagreement at this point. After allowing some general discussion by the children, help them to organize their ideas. They should recognize the fact that in order to forecast the weather, they will need certain kinds of information. See if they can determine just what these are. Data to be included concern local temperature, pressure, humidity (moisture in air), and winds. Bring out the idea that even this information is not sufficient for forecasting, unless it is compared with similar information from the surrounding areas.

For this latter purpose, have a collection of daily weather maps from the newspapers of the past week. Set up a table comparing temperatures, air pressure, humidity, and winds for your city and four locations, each about 100 miles away, to the north, south, east, and west of your city. Using the maps and the table, ask the class if they can see from which direction today's weather came. In general, weather flows toward the east, but winds around pressure areas, mountains, oceans, or lakes can alter this. See if the class can determine a general pattern for your locale.

a hundred years by the Medical Society of South Carolina. As a result, Charleston, South Carolina, has the oldest records of temperature and rainfall in the United States.

It was Benjamin Franklin who first recorded that storms usually come from the south or southwest. He made this observation in 1748 by putting together the weather reports sent to him by mail from different parts of the country. During Franklin's time, the mail moved much more slowly than the weather. Until a faster way could be found to get weather reports from one part of the United States to another, no one could accurately forecast the weather.

Among many other achievements, Benjamin Franklin kept many records of weather conditions.

The Telegraph Reports the Weather

For about a hundred years, scientists worked hard to find a way to get weather reports quickly so that the movement of storms could be forecast. Then, in 1837, the telegraph was invented by Samuel F. B. Morse. A plan was made to have fifty-four telegraph companies in different parts of the United States send their local weather conditions to the Smithsonian Institution, in Washington, D.C.

Every morning the superintendent in the head telegraph office would telegraph the local operators, "Good morning, what is the weather?" The local telegraph operator tapped his key and reported the local temperature, wind, and other weather information. The head office then telegraphed these facts to the Smithsonian Institution, which in turn recorded all the reports from different parts of the country. These reports were put on a large

weather map posted on their wall in Washington, D.C. Weather scientists could gather reports and make forecasts within one hour after obtaining weather information from different parts of the country. Unfortunately, the Smithsonian Institution had no way of broadcasting this information.

Weather Bureaus Are Set Up

Then, eight years later, a French scientist, named Urbain Leverrier (ur-BAN leh-vehr-ee-AY), drew up a plan for an *international system* of telegraphic reports. In 1853, the French weather service was started. The United States followed with a weather service in 1870. It was now possible to forecast the weather with greater accuracy.

Today, weathermen make hourly weather reports in every part of the country. They study these reports and compare them with past records, as well as with present weather conditions. Then they make their forecasts of how the temperature of the air, the pressure of the air, and the amount of water vapor in the air will change. It is the changes in these three conditions that make our weather change.

Following the Weather

The weather in your town today is the result of certain conditions that may have started hundreds or even thousands of miles away. The weather that your town will have next week may be starting right now in some far-off place. And at this very moment, scientists at the weather station nearest your home are studying the travels of these weather conditions.

When the weatherman forecasts "fair during the day and rain at night,"

Leverrier drew up a plan for an international system of telegraphic reports of weather conditions.

As the children understand more about the factors that account for weather, they will probably ask more questions about what will or what might happen. These questions should, in turn, make them realize the need for more information, more records, and more comparisons. The brief history of weather forecasting in this lesson will show the gradual increase in amount of data required for making accurate predictions.

Follow-Up: Let the children discuss the differences between weather and climate.

ADDITIONAL ACTIVITIES:

Pupils can make a three-dimensional geophysical map of your area, to use in conjunction with weather maps from the newspaper. They can make it out of plaster or papier-mâché. This will be an especially interesting activity if you live in an area near a desert, high mountains, or large body of water.

In the past few years, meteorologists have been studying jet streams, and how they may affect weather. (Jet streams were accidentally discovered by bomber pilots in World War II.) Have some pupils investigate these studies, and report on them to the class.

TEACHING SUGGESTIONS
(pp. 228–229)

Background: How does the forecaster predict the weather? One tool is numerical analysis. The motions of the air depend on the known laws of physics, and it is possible for a mathematician to develop equations that will take into account all the major factors that influence the motions of air masses. Unfortunately, these equations are so complicated that they can be solved only with the help of electronic computers, and then the equations must be simplified. Forecasts based upon numerical analysis are useful chiefly in long-range forecasting.

Another tool is the use of statistics. Based on their past experience of how the weather changes under certain given conditions, meteorologists can calculate the chances that the weather will turn colder or hotter, whether it will rain or not. They can thus use weather statistics to help them decide what the weather is going to be. This is what is meant when the local weather bureau says there will be a 75 per cent chance of rain the next day, for example.

don't blame him if you get caught in a shower at lunch time. With all the many ways in which weather conditions can suddenly change, he still does a fine job of forecasting the weather. Why don't you test the weatherman? Make a record of the weather forecasts for two weeks and compare it to the actual weather. *Then* ask, "How accurate is the weatherman?"

The work of forecasting the weather begins by understanding how the temperature, air pressure, and water vapor in the air change—and what causes them to change. To understand this, you must first study the air, where all these changes take place. Then you will better understand how changes in the air make the weather, and why the weather can change so suddenly.

PATHFINDERS IN SCIENCE

Francis W. Reichelderfer

(1895–) United States

In 1963, after twenty-four years as chief weatherman for the United States, Dr. Francis W. Reichelderfer retired. To him, weather forecasting has been a fascinating game of always trying to "beat the weather."

When Dr. Reichelderfer started his career, weathermen flew kites and balloons to gather information about the weather. Early in his career, Dr. Reichelderfer served as co-pilot in a two-man weather-forecasting balloon. There, he learned how to record the temperature, humidity, air pressure, and wind speed. He also

Air Takes Up Space

As you already know, there is air all around you. But you cannot see it, or taste it, or smell it. You can tell that it is there when you feel it moving. Air that is moving is called **wind**. When you are inside your home, how can you tell whether the wind is blowing outside? What are some things you can look for?

Air is a mixture of oxygen, nitrogen, and other gases. There are layers of air surrounding the whole earth. These layers form what is called the **atmosphere** (AT-muh-sfeer).

Air fills up space that looks as if it were empty. When you look at a bottle and cannot see anything in it, you may say the bottle is empty. But is it really empty? You can find out.

observed cloud formations, cloud types, and cloud movements.

Under Dr. Reichelderfer's leadership, the U. S. Weather Bureau began rocketing earth satellites into orbit to probe the atmosphere. Clear photographs of clouds have been radioed directly to the Weather Bureau from the various Tiros satellites which circle the earth. These photographs have identified the cloud patterns that are usually found with certain types of storms. The satellites have been able to probe areas of our universe never before explored by weather forecasting instruments.

It is hoped that in the near future, local weather forecasters will be able to use the weather information from these satellites as easily as they now use information from barometers and thermometers. By using many scientific instruments, today's weather scientists are able to forecast the weather correctly 85 to 90 per cent of the time. Their forecasts are helpful for everybody.

The Weather Bureau, under Dr. Reichelderfer's guidance, started many public services. Among them were crop forecasts for farmers, weather reports for airplanes and ships, and reports on floods and hurricanes. The Bureau now has services that were not thought possible when Dr. Reichelderfer became chief weatherman. Such services are weather forecasts for manned space flights, for rocket flights, and for nuclear tests.

Dr. Reichelderfer is truly a pathfinder in weather forecasting.

Another tool is plain experience. A meteorologist has had a solid education in the science of meteorology and he knows all the instruments and mathematics that are used in making forecasts, but the weather is so complicated that it is rare for a weather change to be absolutely predictable. The meteorologist therefore also uses his experience in interpreting weather maps; he has hunches and intuitions based on his education and experience that help him predict what the weather will be like the next day.

Until about 1920, most weather forecasts were based upon experience. Between 1920 and 1950, statistical analyses helped the meteorologist forecast weather. Since 1950, electronic computers have come into use which help meteorologists provide a more scientific forecast of the weather.

EXPERIMENT

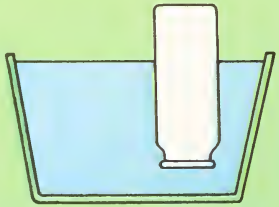
Is an "Empty" Bottle Really Empty?

What You Will Need

vegetable dye 2 bottles pail of water

How You Can Find Out

1. Put a small amount of vegetable dye into a pail of water. Color the water with dye so you can see the water better.
2. Push one "empty" bottle upside down into the pail of water. Hold the bottle with the mouth straight down.
3. Now tilt the bottle. What do you see?
4. Push another "empty" bottle down beside the first bottle.
5. Tilt the second "empty" bottle so that a bubble comes out. Catch the bubble in the first bottle. Continue to do this until there is no water in the first bottle.



Questions to Think About

1. Can you "pour" the air from one bottle to the other?
2. What is now in the first bottle? What is in the second bottle?

Air fills all openings, even if the openings are small. If you push more air into a container, the air pushes harder against the walls.

If the walls of the container can stretch, the added air will push them out. You can see this when you blow up a balloon or pump air into a tire.

TEACHING SUGGESTIONS
(p. 230)

LESSON: Is an "empty" bottle really empty?

Learnings to Be Developed: Molecules of air occupy space.

Developing the Lesson: Proceed with the experiment on this page.

Background: Following are the answers to *Questions to Think About.*

1. Yes. Under water you pour upward rather than downward because the air, being lighter (less dense) than water, will rise in water. As air enters the first bottle it pushes the water out.

2. At the end of the experiment the first bottle contains air and the second bottle is filled with water. The teacher might relate this to conservation of matter.

ADDITIONAL ACTIVITIES:

Take a narrow-mouthed jar such as a gallon jug, and close it with a 2-hole rubber stopper, into which are fitted short lengths of glass tubing. Tie a limp balloon securely over one of the tubes. Connect the other tube to a water faucet with a length of rubber tubing. As you fill the jar with water, the balloon will expand, because air is being displaced from the jar.

EXPERIMENT

Does Air Press on Things?

What You Will Need

glass pail of water

How You Can Find Out

1. Push a glass into a pail of water.
2. Let the glass fill with water. While it is still under water, turn the glass upside down.
3. Lift the glass of water straight up. Lift it high enough so that only the rim of the glass stays below the water.
4. Now lift the glass a bit higher so that the open end is above the level of the water in the pail.

Questions to Think About

1. What happens when you lift the glass so that the open end is just below the level of the water?
2. How does this show that air presses on things?

In this experiment, the air presses down on the water in the pail. The air presses down on the bottom of the glass, too, but the glass keeps the air from pressing down on the water inside the glass. All the air pushing down on the water in the pail is heavier than the water inside the glass. The weight of the air holds up the water in the glass.

You have now learned two important facts about air. Air takes up space, and air has weight.

The air is made of very small parts called **molecules** (MOL-uh-kyoolz). These molecules are much too small for you to see. All objects are made of molecules.

Air molecules are always moving. They are bouncing around in all directions. If air is heated, the molecules will move faster and bounce farther apart from each other. In warm air, the molecules are farther apart than in cold air. There are not as many air molecules in a gallon bottle of

TEACHING SUGGESTIONS
(pp. 231–232)

LESSON: Does air press on things?

Background: The atmosphere of air that envelops all structures on earth, acts as an "invisible shield" of protection against objects flying in from outer space. It slows down most meteors that the earth encounters, and causes them to be burned up by friction. It shields us from certain harmful radiations of the sun, and from certain other particles, such as cosmic rays, whose origins are uncertain.

The atmosphere extends very high up above the earth (probably more than 400 miles) and the weight of a column of air upon 1 square foot of the earth's surface is about one ton (15 pounds per square inch × 144 square inches).

The atmosphere is divided into several zones, the first of which is the troposphere, which extends about 7 miles high. The stratosphere is next, about 3 miles high, with a temperature range from −50° F to −100° F. Third is the ozonosphere, about 20 miles thick. It contains a form of oxygen called ozone, which absorbs much of the sun's ultraviolet light and thus saves us from severe sun-

burns and possible blindness. The last layer is the ionosphere, so called because the air particles in it are electrically charged (ions are electrically charged particles). This is the layer that makes radio broadcasting possible.

Learnings to Be Developed:

Air is made of molecules.

Air has weight.

Weight is a property of matter.

Developing the Lesson: It is not always easy for children to grasp the idea that air has weight. You might demonstrate this in a very simple manner by weighing an inflated basketball or football bladder on a platform scale. Then deflate it, and weigh it again.

For a dramatic demonstration of the pressure which air exerts, use a square-cornered can and remove the air from it with a bicycle pump. The can will be crushed. Explain to your pupils that as the air pressure inside the can was reduced, the outside air pressure, no longer being balanced, crushed the can.

50° F. 75° F.

On the left is a closed room. Is the air moving? On the right the heat is turned on. What happens to the molecules of air in this room?

warm air as there are in a gallon bottle of cold air. Therefore, a gallon of warm air weighs less than a gallon of cold air. In the gallon of warm air, the faster-moving air molecules spread farther apart, so that fewer of them fit into a bottle. In the bottle of cold air, the slower-moving molecules are closer together, so that more of them are crowded into the bottle.

How Air Moves

Can you feel the air? Not unless it is moving. When you use a fan to push the air, you can feel the air move. You have made a *wind*. Wind is air that is moving. We will need to find out more about air to understand what makes it move.

You have learned that warm air is lighter than cold air. Then, of course, cold air is heavier than warm air.

You might ask, "What does this have to do with the weather?" Let us suppose that it has become cold in your room. The temperature is 50° F. The molecules of air in the room are moving at a slow speed. Now, suppose you turn on the heat. As the air becomes warmer, its molecules move faster and push farther apart. In the warmer part of the room, where the heat is coming from, there are fewer air molecules than in the cooler parts.

Now let us see what is happening on the cooler side of the room. In the cold air the molecules are crowded more closely together than they are in the warm air. The cold air molecules move across the floor toward the area where the air is warmer and lighter. There is more room there. The cold air now becomes warmer and, therefore, lighter. As it becomes warmed, more cold air moves in and it pushes the warmer air up and across the ceiling to the other side of the room. But as it gets to the cooler side of the room, it again becomes cooler. It sinks to the floor and moves again toward the warmed side of the room.

The hotter the air becomes, the faster it moves up, across, down, and back. From what you have just learned, explain what happens to the air in a room when you open windows from top and bottom. What happens when the air on both sides of the room becomes heated to the same temperature?

Let us now find out how outdoor air gets heated. We would need a giant-size radiator to heat all the air. The *earth* is this giant radiator. When energy from the sun has warmed the earth, the earth becomes a huge radiator. You have felt how hot the sand at the beach can become. The sun heats not only the sand, but all kinds of soil and rocks and water. Just as the radiator in your room heats the air nearest it, the earth heats the air nearest it. This causes the molecules making up the warm air nearest the earth to move faster and farther apart. The warmed air also becomes lighter as this happens. It is pushed up by the cooler air, just as the air in your room is pushed up when it is warmed.

The Weather Is Different in Different Places

You know that the weather is not the same everywhere. Do you know why? Here are some of the reasons. The surface of the earth is different in many places. Some places are covered with rocks or soil or sand. There are forests, mountains, prairie lands, and deserts. Other parts of the earth are covered with water. There are streams, rivers, lakes, and oceans.

Does the sun heat all these different surfaces exactly the same amount? You can find out easily by doing the next experiment.

TEACHING SUGGESTIONS
(p. 233)

LESSON: What causes air to move?

Learnings to Be Developed:

Air moves in the atmosphere because some places heat it and others cool it.

Unequal heating causes air to move.

Developing the Lesson: Here is a demonstration of how air moves when temperature changes, that should baffle and intrigue your pupils.

Before class, attach a balloon to a Florence flask and place it in the freezer compartment of the refrigerator. In about one hour, the air in the flask will have contracted so much that the balloon will be "drawn" inside the flask. The air in the flask contracts so much as it gets cold that the warmer outside air pushes into the flask, pushing the balloon in front of it. Show the flask to the class without explanation and challenge the pupils to duplicate the result with other flasks and balloons. As they handle the experimental flask, and as it stands around in the warm room, the balloon will slowly come up and out of the flask. A lively discussion should develop.

EXPERIMENT

Does the Sun Heat All Surfaces the Same Amount?

What You Will Need

soil — 2 coffee cans
water — thermometer

How You Can Find Out

1. Fill one coffee can with soil. Measure its temperature.
2. Fill the other coffee can with water of about the same temperature as the soil.
3. Now put both cans on the same sunny window sill for 20 minutes.

Questions to Think About

1. Do the contents of the cans feel alike in temperature?
2. Now use a thermometer. What does the thermometer read for each can?

You have just found that, in sunlight, soil heats up faster than water. Most materials heat up faster than water. Buildings and sidewalks all heat up faster than water.

Land heats up faster than water. That is why people who live in the city go to the beach or a swimming pool in the summer to cool off. One of the reasons that land heats up faster is that sunlight heats the surface of the soil, but it cannot easily pass through the soil to heat the part below the surface. Most sunlight warms only the surface of the earth. But the same amount of sunlight can shine right *through* water and can heat the water down to a certain depth.

Have you ever looked down at the earth from an airplane or from a high lookout on a mountain road? If you have, you have seen that the earth is not the same color everywhere. Some places are dark-colored and others are light-colored. Some are green, others are brown. Could this make a difference in the way the earth is heated by the sun? You can find out.

TEACHING SUGGESTIONS
(pp. 234–235)

LESSON: Does the sun heat all surfaces equally?

Background: We have just determined that changes in the temperature of air, causing it to contract or expand, result in the movement of air. Heat is the form of energy which causes molecules to be greatly agitated and thus to move more rapidly. Temperature is a measure of that movement.

Learnings to Be Developed: The amount of heat absorbed by a substance depends on the material and its surface color.

Developing the Lesson: Before attempting the experiments on these pages, it would be wise to let your pupils fully understand the necessity for using precise measuring instruments, such as a thermometer.

Fill a bowl with a mixture of hot and cold tap water, so that it is approximately room temperature. Fill a second bowl with very warm water, and a third bowl with cracked ice and water. Divide the class into two teams. Each member of Team A is to put a hand into Bowl #2 for several moments, and then plunge the same hand into Bowl #1. Their verdict

Are Things of Different Colors Heated Equally Fast by the Sun?

What You Will Need

large pieces of white, red, blue, and black cloth
thermometer

How You Can Find Out

1. Put pieces, about 5 inches by 5 inches, of white, red, blue, and black cloth in a sunny window.
2. Feel them with your hand after a while. Are some of them warmer than the others?
3. If you have thermometers, place one under each of the pieces to make sure.

Questions to Think About

1. What is the temperature under each piece of cloth?
2. Why should you try to use a thermometer rather than your hand to see which is warmer?

Have pupils tell ways in which color is used to make us more comfortable (the colors of the paint on and in houses, colors of summer and winter clothing, etc.).

Look at the patches of land. Are they heated differently? Explain your answer.

will be that the water in #1 is cooler. Each member of Team B is to do the same thing, using Bowl #3, and then Bowl #1. Their verdict will be that the water in Bowl #1 is warmer.

Discussion of this experiment will bring out the fact that neither team was right—or that both teams were right—in their decision about the temperature of Bowl #1. In any case, it will be obvious that some more precise measure of "warm" or "cool" is needed—a thermometer.

Background: Following are the answers to *Questions to Think About,* page 234.

1. Possibly. Only if the sun is very strong, the soil will feel warmer to the touch.

2. The thermometer reading should be higher for soil than for water.

Following are answers to *Questions to Think About,* page 235.

1. The darker cloths should yield higher readings. Try to use cloths of equal texture and thickness. The experimental factor is color. The controls are thickness, texture, and sunlight.

2. Touch is not an accurate measure.

TEACHING SUGGESTIONS
(pp. 236–237)

● **LESSON:** Do clouds affect the temperature of the earth and air?

Background: Land heats up faster than water, as our experiments on pages 234–235 show. It also loses its heat more quickly. Our atmosphere is primarily heated by being in contact with the land (heating by conduction) and by radiation from the earth, rather than by radiation from the sun. The heat from the earth is absorbed by water vapor, clouds, and the carbon dioxide in the atmosphere. This is called the "hothouse effect" and is very important to life. If the heat thus trapped were able to escape into the upper atmosphere, the normal temperature of the earth would be so low that life could not exist. The experiment on page 237 shows the cooling effect of clouds in the daytime. However, because of the "hothouse effect," clouds perform the opposite action at night. They tend to trap the heat radiating from earth, and to reduce the rate of radiation loss. That is why a clear night is usually so much colder than a cloudy night; on a clear night heat radiates rapidly out to space.

You have found out another reason that land heats up faster than water. *Darker things usually heat up faster than lighter ones, and most land is darker than water.*

Here is another reason for the differences in the way the earth is heated by the sun. On a hot sunny day, when you are outdoors, you feel much cooler when a cloud comes between the sun and the earth. Clouds shade the earth. When this happens, the sun cannot heat the shaded places as much. You can show how this happens.

This picture shows how clouds shade various parts of the earth. Can you tell how this shade affects the amount of heat different parts of the earth receive?

EXPERIMENT

Does Being in the Shade Affect the Temperature?

What You Will Need

2 glasses of water large piece of paper thermometer

How You Can Find Out

1. Take the temperature of the water in each glass.
2. Now put them both near the same sunny window.
3. Place a large piece of paper over only one of the glasses. (This paper covering is your "cloud" and throws a shadow on the water.)
4. After an hour, take the temperature of the water in each glass again.

Questions to Think About

1. Compare the temperatures. Which one is warmer?
2. Can you think of another experiment to do that shows how being in the shade changes the amount of heat an object gets?

Take the two coffee cans—one with water, the other with soil—that you used for your experiment on page 234. Before leaving school for the day, use a thermometer to find the temperature of the soil and the water. Next morning, as soon as you get to school, take the temperature again. Is there a change?

At night, the soil and water on the earth are no longer heated by the sun. They lose heat and become cooler. From the experiment that you just did, using the water and the soil, you found that *soil cools off faster than water does.*

Making Winds

During the daytime the sun warms the earth. And so the air over the land becomes warmer than the air over the water. The cooler, heavier air moves in from the water and pushes

Learnings to Be Developed: Clouds prevent the sun's radiation from reaching the surface of the earth in daytime.

Developing the Lesson: Discuss the questions on the experiment on page 237. Have pupils make predictions about the results before the experiment is complete. Compare these later with actual outcomes.

Background: Following are the answers to *Questions to Think About,* page 237.

1. The unshaded glass should be higher in temperature. If the area around the glasses is breezy, the results might be different, so shield them from excess breeze. Be sure the "cloud" is very opaque paper, or else the hothouse effect could reverse your findings.

2. Any shielding setup that eliminates wind and the hothouse effect in its design should be acceptable.

TEACHING SUGGESTIONS
(pp. 238–239)

● **LESSON:** How do winds affect weather?

Background: The anomometer is limited in its usefulness since it gives information only about surface winds. Meteorologists need information about the winds at the altitude of airplane travel, and even higher, if they are to produce accurate long-range forecasts. For this purpose, radar is used. Weather balloons are sent aloft, and radar scopes spot their direction and rate of movement. The balloons bring back other information as well, on humidity, temperature, and pressure, from instruments which are attached and sent aloft with them.

Jet streams are studied in this way also. These are "rivers of air" with speeds of 100 to 200 miles an hour, flowing between 5 and 7 miles above the earth. They have been likened to the Gulf Stream, which is called a "river within an ocean." The jet streams are affected by the temperature of the surface air, and they in turn affect the surface weather. The patterns of change produced by the jet streams have yet to be determined. This knowledge will

After reading the text below, study the pictures above very carefully. Then see if you can describe what is happening in each of the pictures.

the warmer, lighter air up. The air moves in a big circle. The air goes up from the land across to the water and down toward it. Then it moves across, toward the land, up, back across toward the water, and down again. This happens over and over again. The wind blows from the water to the land as long as the sun keeps the land warmer than the water.

At night, the land and the water are no longer heated by the sun. They lose heat. They get cooler. You already know from the experiment on page 234 that the land will cool much faster than the water.

At night, when the air over the water becomes warmer than the air over the land, the air again moves in a big circle. But now the direction of the moving air is just the opposite of what it was during the day. The warmer air over the water is pushed up by the cooler air coming from the land.

There are always warm spots and cold spots on the earth. The air above becomes warm or cold from the spots beneath it. Cold air moves toward the warmer air and pushes it upwards. This explains why there are always winds blowing somewhere.

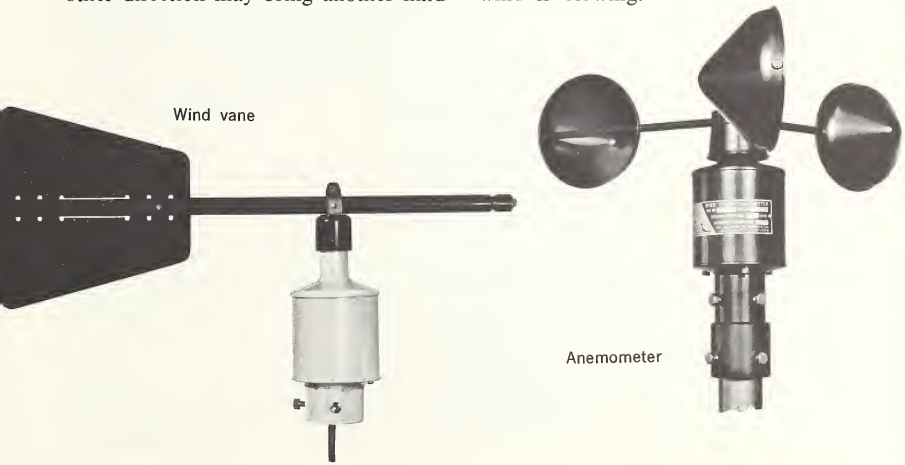
It is the sun's energy and the air around the earth, working together, that make the winds.

Why Wind Direction Is Important

When scientists forecast the weather, they need to know about the wind. Winds from one direction may bring one kind of weather. Winds from another direction may bring another kind of weather. Knowing the direction of the wind helps weather scientists forecast the weather. Knowing how fast the winds are moving helps these scientists tell how soon the weather is likely to change.

Weather scientists have an instrument to measure the speed of the wind. This instrument is the **anemometer** (an-uh-MOM-uh-ter).

The anemometer in the picture has cups that turn a rod when the wind blows against them. The speed with which the rod spins is recorded on a dial. In this way the weather scientist knows how many miles an hour the wind is blowing.



greatly assist meteorological long-range forecasting.

Learnings to Be Developed:

Winds carry warm or cool air to a locale.

Winds can carry moisture.

Wind speed is measured by an anomometer.

Wind direction is shown by a weather vane.

Developing the Lesson: Discuss the illustrations of land and sea breezes on page 238. Bring out the fact that not all of us live near the ocean, or near any large body of water. Some live in mountains, and others live in valleys. Discuss how winds move in those places. In a valley, for example, warm air rising during the daytime will cause a "valley breeze" to move up the surrounding mountainsides. At night, the cool, heavy, mountain air, sinking into the valley, will cause a "mountain breeze" to move down the mountainsides.

Finding Wind Direction

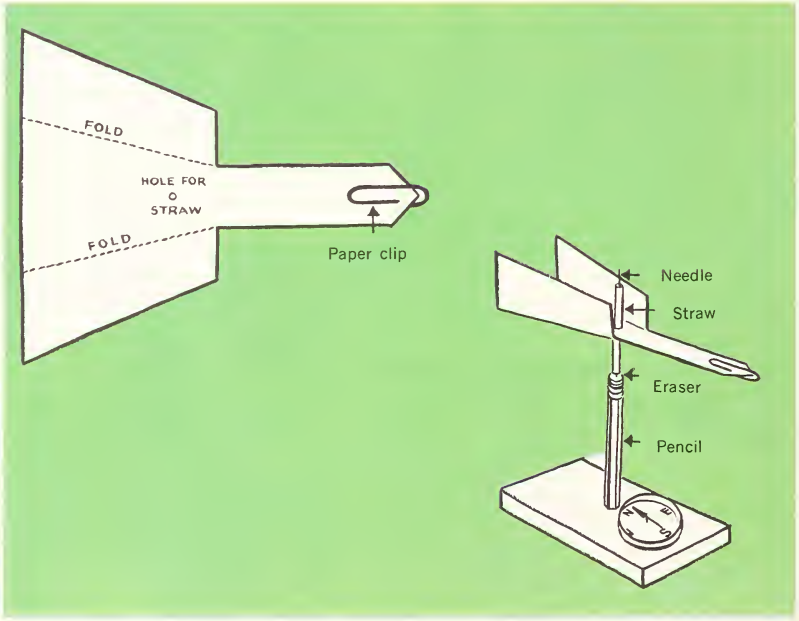
The **wind vane** or weather vane is an instrument for finding the direction the wind is coming from.

The picture shows you how to make a simple vane. Use heavy cardboard. The kind used for shoe boxes is good. Make all the holes small, so that everything will fit tightly. Be sure that the turning point is at the right place for the vane to swing freely.

You will need to place your wind vane away from anything that might block the wind.

Using a compass, place the box so that the **N** points to the north. When the wind blows, the pointer of the vane will point in the direction from which the wind is coming.

A wind that comes from the south is called a south wind. A wind from the north is called a north wind.



TEACHING SUGGESTIONS
(p. 240)

Background: This might be a good place in which to show a film.

Films:

The Unchained Goddess (29 min., color, American Tel. and Tel. Co.). Available on free loan from your local telephone company. Excellent details on what science has learned about winds, clouds, precipitation, and lightning.

Operation Hurricane (14 min., b/w, U.S. Weather Bureau). The nature of hurricanes, their origin, their travel, and how information is gathered about them.

Air All About Us (11 min., b/w, Coronet). A floating feather makes David aware that the earth is surrounded by an ocean of air which exerts pressure in all directions. He is then able to explain the use of air pressure in suction cups, tires, a car lift, and airplanes.

How Weather Is Forecast (11 min., b/w, Coronet). Included in the film are scenes of a weather forecasting station in operation, the charting of weather maps, and forecasting. The importance of weather to farmers, airlines, fishermen, and the inhabitants of flood areas is discussed.

Using What You Have Learned

1. You can tell about how fast the wind is blowing by watching your school flag. Below, you will see a chart that tells you how the wind affects a school flag.

Flag hangs limp	Wind less than 4 mph
Flag flaps occasionally	Wind 4 to 7 mph
Flag waves	Wind 8 to 12 mph
Flag stands out from pole	Wind 13 to 18 mph
Flag pulls rope with it	Wind 19 to 24 mph
Flag snaps as it flaps	Wind 25 to 31 mph
Flag must be taken in	Wind more than 31 mph

2. Pick a committee to make a special exhibit or a scrapbook called "Weather in the News." The committee should keep daily records of the weather and cut out the weather maps from the newspaper. The committee should also look in the newspapers to see if they can find stories about how the weather has affected people.

3. You can find out what would happen if air could not press down on the water in a glass. Cut off the end of a balloon. Then take the balloon and pull one open end down over the neck of a small bottle filled with water. Fasten the balloon tightly to the bottle with a rubber band. Then slip a glass tube through the other end of the balloon, and fasten this end tightly around the tube with a rubber band. Now suck through the tube. What happens?

TEACHING SUGGESTIONS
(p. 241)

The three exercises do not require any further information. Perhaps you might like to introduce the terms used in U. S. Weather Bureau Forecasts to refer to winds.

Light—1 to 7 mph
Gentle—8 to 12 mph
Moderate—13 to 18 mph
Fresh—19 to 24 mph
Strong—25 to 31 mph
Gale—32 to 74 mph
Hurricane—75 mph plus

Some questions could be posed here as additional application of learnings.

- *Suppose the temperature of the air never changed. Would we have any wind?* (No, except for what might be caused by friction against a spinning globe.)

TEACHING SUGGESTIONS
(pp. 242–244)

● **LESSON:** Does the weight of air change?

Background: The text on page 244 is actually describing the water barometer made by E. Toricelli, in the 17th century. His measurements came out to about 10 meters, or 34 feet.

There may be a mercury barometer in your school, but it is more likely that any barometer in a pupil's home would be an aneroid barometer. The aneroid barometer consists of a waferlike metal container, from which most of the air has been removed. A pointer is attached to this, which moves across a scale calibrated to deliver information on air pressure.

Learnings to Be Developed:

The air pressure at any spot on earth is the weight of a column of air above that spot.

Air pressure on earth is about 15 pounds for every square inch.

Air pressure decreases as altitude increases.

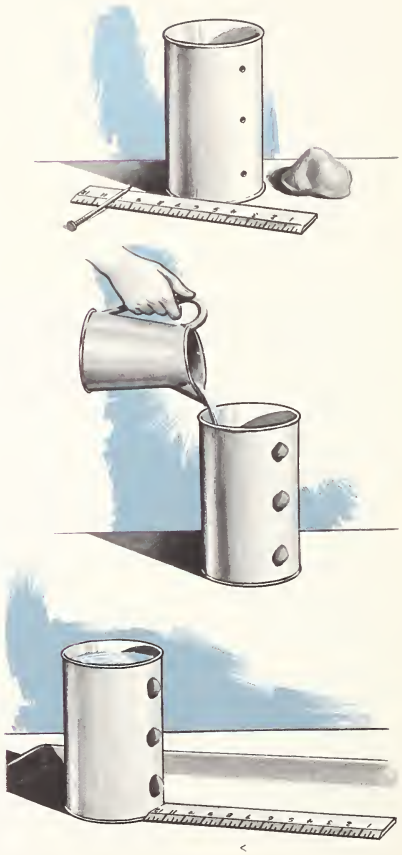
Developing the Lesson: To reinforce the idea introduced earlier, that air has weight, perform the following simple demonstration.

How Air Acts

You already know that air has weight. This means that gravity pulls air toward the center of the earth.

When you pile things higher and higher, the weight, or downward push, at the bottom becomes greater. Suppose you piled books one on top of another on a scale. The more books you put on, the heavier the push against the scale would become.

You can see how this works with water. Water often acts much like the air. Take a quart juice can. Punch three holes at the side of the can: one hole near the bottom; one hole above it, halfway up; and a third hole near the top. Plug each hole with modeling clay. Fill the can with water. Put a 12-inch ruler alongside the can. Remove the lowest plug. Measure the distance the water shoots out. Return the plug to the hole. Refill the can with water. Next, pull out the middle plug and measure the spurting water. Return this plug to the hole and refill the can with water again. Now remove the top plug of clay and observe what happens. From which opening did the water shoot the farthest? From which



What will happen as you pull out each plug?

the least? At which opening was the pressure of the water greatest? Why?

Air is not solid, like books. Nor is it a liquid, like water. You cannot squeeze water molecules much closer together by pressing on them. But when you press down on air, you squeeze the molecules of air closer together.

It is a little like making a big pile of hay. The more hay you throw on the pile, the more gravity pulls on it and the more the hay pushes down. The hay at the bottom is packed closer together by the weight of the hay above.

High up in the air, or at the top of a mountain, the molecules in the air are not packed so closely together as they are farther down. The air that fills a gallon or a quart bottle near the earth is heavier than the same amount of air higher up. Air gets lighter as you move away from the earth.

With a crayon or piece of colored chalk, draw a square an inch on each side on the back of your hand. Now try to imagine a column of air reaching up as far as there is air. Scientists believe the column would have to be at least 700 miles high. If you could weigh the column of air touching one square inch of your skin, it would weigh almost 15 pounds. "Almost 15 pounds" is the way we express the pull of gravity on the air in that imaginary column. You can see that the weight or pressure of air on your whole body is very great. The air pressure at any spot on the earth is the pressure of the air above that spot.

You do not feel the weight (almost 15 pounds for each square inch) because it presses on all sides of your body. If it did not press equally on all sides, you would cave in. Sometimes, when the air pressure around you suddenly changes a great deal, you can feel the change in your ears.

Perhaps you have gone up in an airplane, or in a car to the top of a high mountain, or in an elevator to the top of a very tall building. Do you remember feeling the sudden change in air pressure in your ears?

Weighing Air

The weight, or pressure, of the air changes. It changes as you climb a mountain or go up in an airplane. It changes as the air is heated by the earth. It changes when the air loses some heat and becomes cooler. When

Pour a small amount of vinegar over some baking soda in a glass. Carbon dioxide, an invisible heavy gas, will soon fill the glass. Now take a birthday candle and light it. Hold the glass over the lit candle and pour the invisible gas over the flame as shown in the diagram. The heavy gas flows and smothers the small flame. Ask the children:

- *Is the gas from the glass heavier or lighter than air?* (Heavier, as evidenced by its downward flow.)

To introduce the principles of a barometer, ask children to recall the blood pressure instruments their doctor uses. In his office, the doctor may have a mercury instrument. In his bag, he probably has a portable aneroid instrument. Perhaps you can ask the school doctor, or nurse, to display both instruments and explain to the pupils how they work.

Follow-Up: The principles of the aneroid barometer can be demonstrated with the following project. Tie a piece of plastic film or thin rubber sheeting over a shallow can or jar. Glue a straw to the center of this covering, at right angles to it, so that it extends away from the jar for most of its length. Glue

a sharp splinter of wood to the other end of the straw as a pointer, and place it in front of a fixed scale or ruler. Calibrate the scale against the mercury barometer or against the local weather report.

This barometer will probably work, but it will most likely not be accurate. Discuss the reasons for this with the class. They may include such factors as the cover not being air tight, so that as the pressure changes, the air volume in the can adjusts itself; or the plastic film may stretch in response to humidity changes in the air; or the confined air in the can may maintain a fairly steady temperature even though the outside air is changing.

○ **ADDITIONAL ACTIVITIES:**

Inflate a balloon; tie the neck securely. With a string or tape, measure the balloon at its greatest circumference (distance around). Place the balloon in the sunlight, on top of a radiator, or in some other warm spot. In about ten minutes, measure the circumference again. What has happened?

air pressure changes, it usually means the weather will change. Weather scientists measure air pressure to help them predict the weather. They have instruments to measure air pressure. Any instrument used for measuring air pressure is called a **barometer** (buh-ROM-uh-ter). Now you will find out how a barometer works.

When the glass on page 231 was lifted slowly out of the pail of water, the water stayed in the glass. The air pushing down on the water in the bucket held it there. You could try a taller glass, and it would still work. You could keep trying taller and taller glasses, and it would still work. It would work until you had a glass 34 feet tall. Then some of the water would fall out of the glass.

If you were a giant and you had a glass 35 feet tall, you could try it out in a lake. If you did this, you would find that air pressure at sea level would hold the water only up to about 34 feet. In other words, the weight of the air, and the weight of 34 feet of water in the glass, balance each other.

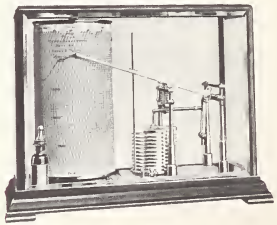
If the air pressure were less, some of the water in your giant glass would drop out.

Of course, such a tall glass would be very difficult to use. So instruments for measuring air pressure use a liquid heavier than water. With a heavier liquid, we can use a shorter tube. It has been found that a good liquid to use is *mercury*, because it is 13 times heavier than water. At sea level the weight of the air will push mercury about 29 or 30 inches up the tube.

A barometer that uses mercury is called a **mercury barometer.** We read the barometer by noting how many inches the mercury is pushed up in the tube. In this way, weather scientists

A typical mercury barometer used by the United States Weather Bureau.

The type of barometer below, called a barograph, records air pressure changes on paper. A pen fastened to the arm writes on the paper as the drum turns.



can compare pressure changes from day to day, or even from hour to hour. When the weather scientist says the barometer reading is 30, he means that the mercury is 30 inches high in the tube. Does this mean that the air is pressing hard, and that the pressure is high?

Above 30 inches, barometer readings are called high; below 30 inches, low.

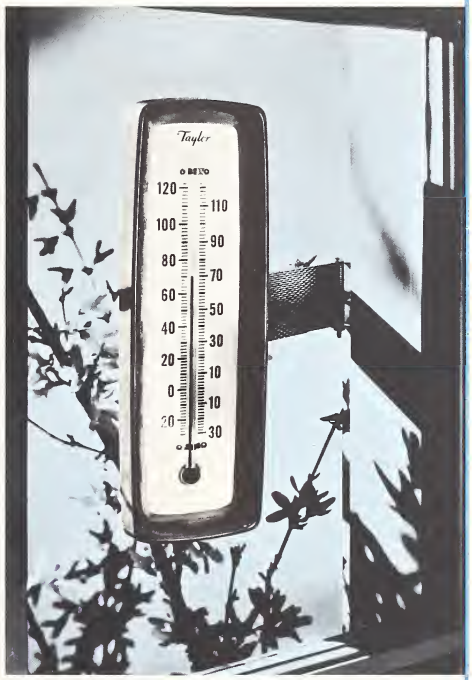
Measuring the Air Temperature

How do you know what to wear to school? Usually you listen to the weather forecast on the radio in the morning. You listen especially for the temperature. If the temperature is in the 30's, you wear warm clothes. If the temperature is in the 80's, you dress lightly. A **thermometer** is used to measure the temperature.

It is hard to make a thermometer, but you can learn how thermometers work. You know that air is made of very small parts called molecules. You also know that when air is heated its molecules move faster and farther away from each other.

Liquids are also made of tiny molecules. Molecules of liquid are packed much more tightly together than air molecules. They cannot move as freely or as far apart as air molecules.

When a liquid is heated, its molecules start to move faster. They spread farther apart, too. They take up more space.



What happens to the height of the column of liquid in the glass tube as the temperature of the air rises and falls?

TEACHING SUGGESTIONS
(pp. 245–246)

● **LESSON:** What happens when a fluid is heated?

Background: Liquids, solids, and gases all expand when heated. When energy is added to a system, the individual molecules in the system increase their movement and tend to require more intermolecular space. Because of the increase in their velocities, they rebound from each other further on each impact. In a fluid, (gas or liquid) this is more noticeable than in a solid.

The experiment on page 246 uses a liquid. Explain to your pupils that gases behave in the same manner.

Learnings to Be Developed:

A thermometer is used to measure temperature.

Fluids expand when heated.

Developing the Lesson: Collect a number of thermometers which are designed for use in the home. Place them side by side on a table and check to see whether they all register the same temperature. Place them all in a beaker of ice water and observe their readings. Repeat in a beaker of warm tap water. Discuss the differences in readings that you will observe.

- *Are such inconsistencies important in our daily lives?*
- *Would they be important to a baker?*
- *To a scientist?*
- *To a farmer?*
- *Is a thermometer useless if its scale does not indicate the correct temperature?*

Background: Following are the answers to *Questions to Think About,* page 246.

1. The water rises in the glass tube as the bottle is heated. As water is heated, its molecules move faster and faster. They move greater distances.

2. The water level in the glass tube goes down. The molecules in the water move slower and slower. They travel shorter distances.

EXPERIMENT

What Happens When a Liquid Is Heated?

What You Will Need

small bottle	glass drinking tube*	rubber band
balloon	adhesive tape	scissors

How You Can Find Out

1. Cut the neck off a balloon.
2. Slide a glass drinking tube through the part of the balloon which you have cut off.
3. Fasten the neck of the balloon tightly to the drinking tube with a rubber band.
4. Fill a small bottle to the top with water and then stretch the balloon over the mouth of the bottle.
5. Put a little more water in the glass tube and mark the water level with a piece of adhesive tape.
6. Heat the water in the bottle by placing it in very hot water.

Questions to Think About

1. What happens as the water in the bottle becomes hot? Can you explain why this happens?
2. What happens when the water in the bottle cools?

*A paper straw would probably collapse. Try it and see. (Air presses it flat.)

Thermometers usually have mercury or alcohol in the glass tube instead of water. When the mercury is heated by the air, the molecules in the mercury move faster and farther. They take up more room. But there is no place for them to go except up in the tube.

The **scale** on the tube shows how far up the tube the mercury reaches. The marks on the scale are called **degrees.**

Some thermometers are marked with the **Fahrenheit** (FAR-un-hyt) scale. On the Fahrenheit scale, water freezes at 32 degrees. This is written 32° F.

Water in the Air

On page 224 you read how the weather is affected by changes in the air. You have read how changes in the temperature and pressure of the air cause winds. The amount of water in the air also affects our daily weather in many ways. And so, the weather scientist needs to know about water in the air as much as he needs to know about air temperature and air pressure.

Without water in the air, there could not be fog or mist or clouds. There could not be rain or snow.

How Water Gets into the Air

Water molecules, whether they are in great bodies of water or in small puddles, are always moving, but not all at the same speed. There are always some molecules moving faster than others. Some move fast enough to escape from the surface of the water into the air.

These runaway water molecules move in among the air molecules. Then they are called water vapor. The escape of water molecules into the air is called **evaporation** (ih-vap-uh-RAY-shun). Other liquids can evaporate too.

As water is cooled, its molecules move slower and slower. They move shorter distances. Evaporation is slow.

As water is heated, the molecules move faster and faster. They move greater distances. Evaporation is fast.

The water molecules at the top of a container escape first. Those at the bottom cannot escape because the molecules above press down on them. The larger the surface of the water, the more molecules escape.

Do you see why the same amount of water will evaporate more slowly from a full cup than from a pie plate?

TEACHING SUGGESTIONS
(pp 247–248)

● **LESSON:** How does water get into and out of the air?

Background: Humidity refers to the invisible water vapor that is in the air. Rain, clouds, fog, and snow are visible forms of water and are not included in the term humidity.

Molecules of water vapor displace air molecules as they enter the air. As the humidity of the air increases, the number of air molecules decreases. Each molecule of water vapor weighs less, on the average, than the molecule of air which it displaces. Therefore, a given volume of air weighs less when it is humid.

Learnings to Be Developed:

Water vapor is an invisible gas.

When individual molecules of water escape from a liquid, we say that evaporation takes place.

When water vapor molecules accumulate, or come close together, condensation takes place.

Developing the Lesson: Rub a wet sponge over the chalkboard and watch the film of water evaporate into the atmosphere of the room.

• *Where did the water go?*

• *Can we see the evaporated water?*

Repeat, using some rubbing alcohol from the nurse's office on one section of the board, and the wet sponge on another section.

• *Do both evaporate?*

• *Does the alcohol evaporate faster or slower than the water?*

After the alcohol disappears, ask one of the children to smell the area around the board.

• *What does the odor imply?* (The molecules of alcohol are still present in the air, as a gas. Because they are so far apart, we cannot see them.)

Relate this activity to the text.

In discussing the cooling off of moist air, have children recall how, in very cold weather, the moisture in their breath forms a small, visible cloud. Point out that water vapor is constantly being breathed out, but because the air around us is usually close to body temperature, it does not condense and we cannot see it. To illustrate condensation in the classroom, supply each child with a small mirror or piece of shiny metal. Have pupils breathe heavily against these and notice the moisture formation.

How Water Gets Out of the Air

If water did nothing more than evaporate, soon all the water on the earth would evaporate into the air. All the earth's water would become water vapor. There would be no water for plants and animals. Plants and animals could not live.

But water vapor can come out of the air as well as go into it. When water vapor changes to a liquid again, we call it **condensation** (kon-den-SAY-shun). Condensation is the opposite of evaporation.

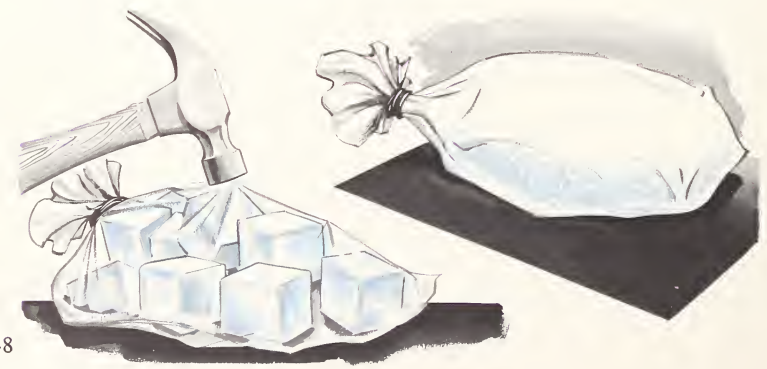
You can make some good guesses about how water condenses if you can remember how water gets into the air. Water molecules have to move very fast in order to get into the air. Anything that slows them down will cause them to come closer together. Then they will change back into water again.

Heating makes molecules move faster. Cooling makes molecules move slower. Condensation is caused by cooling.

Clouds

Clouds are made from tiny drops of water or bits of ice. You know that both water and ice are colorless. Then why do clouds sometimes look white? To see why clouds appear to be white, try this. Get a clear ice cube or some pieces of ice. Put it into a bag

Crush the ice with a hammer. What is the color of the crushed ice?



and crush it with a hammer. The colorless ice, now in many pieces, looks white.

Whenever you crush an ice cube, you break its six smooth surfaces into many tiny pieces, all facing in different directions. The light striking all these surfaces is scattered in all directions and makes the colorless ice look white.

The water droplets and the ice crystals in the clouds scatter the sunlight in the same way.

Rain and Snow

Steam is very hot water vapor. You remember that you cannot see steam. Boil some water in a kettle. Is there a little distance between the white cloud that is formed and the spout of the kettle?

The steam is in the space between the spout and the little white cloud. The cooler air away from the spout cools the steam. The water molecules are slowed down by the cooling. When they slow down they come closer together. They condense. The cloud is really tiny drops of water floating in the air.

Hold a cold plate so that the steam strikes it. The cold plate makes the steam condense much faster. The tiny drops of water come together and make big drops of water. They fall from the plate like rain. But real rain is not quite so easy to explain. Not all weather scientists agree as to how rain and snow are made high in the air.

Scientists think that water will not condense unless there is something on which it can condense. But on what could water vapor condense high in the air?

Many scientists think that water vapor condenses on tiny particles of dust in the air. Then the vapor collects into tiny drops of water and forms a cloud.

How does this demonstration give you an idea of the way in which rain is formed?

TEACHING SUGGESTIONS
(pp. 249–255)

LESSON: What forms does condensation take?

Background: Condensation and precipitation are caused primarily by cooling. The capacity of a given amount of air for water vapor is greatly reduced when the temperature drops. When the vapor capacity is reduced below the actual amount of vapor present, the air becomes saturated and the excess vapor condenses to form a cloud of water droplets or ice crystals, depending on the temperature.

Most heavy rain forms by the rapid lifting of air in clouds containing ice crystals, as well as water droplets, at temperatures below 0° C (32° F). In middle latitudes in the summer time, these low temperatures can be found above 15,000 feet. The ice crystals grow and combine with each other to make snowflakes or hailstones, and then melt into large raindrops on their way down to the ground. On the other hand, water droplets in normal clouds generally do not grow any larger than drizzle size. Most artificial rainmaking has been done by creating ice crystals.

Learnings to Be Developed:

Clouds are condensed water drops and ice crystals.

Water vapor condenses on dust particles in the air.

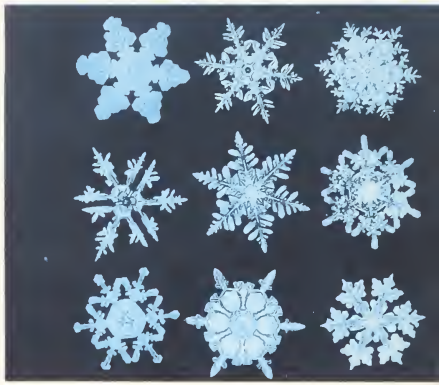
Hail and sleet are frozen water drops.

Snow is an ice crystal.

Developing the Lesson: Ask the pupils whether they have ever seen condensation. List the examples they mention on the chalkboard.

Now try a demonstration. Place some ice and water in a metal can. The ice will quickly make the can cold. The cold metal will then cool the air directly outside the can, and the water vapor in that air will condense on the sides of the can. Wipe the outside of the can dry with a handkerchief and watch the moisture reappear. Relate this to the condensation on the outside of cold water glasses on a hot day.

To convince your pupils that the moisture is not seeping through the metal, fill the can with water at room temperature. No condensation will occur. Another variation would be to add a few drops of ink to the water and ice mixture. Wipe the moisture from the can and check for the color on the cloth.



SNOWFLAKE PATTERNS

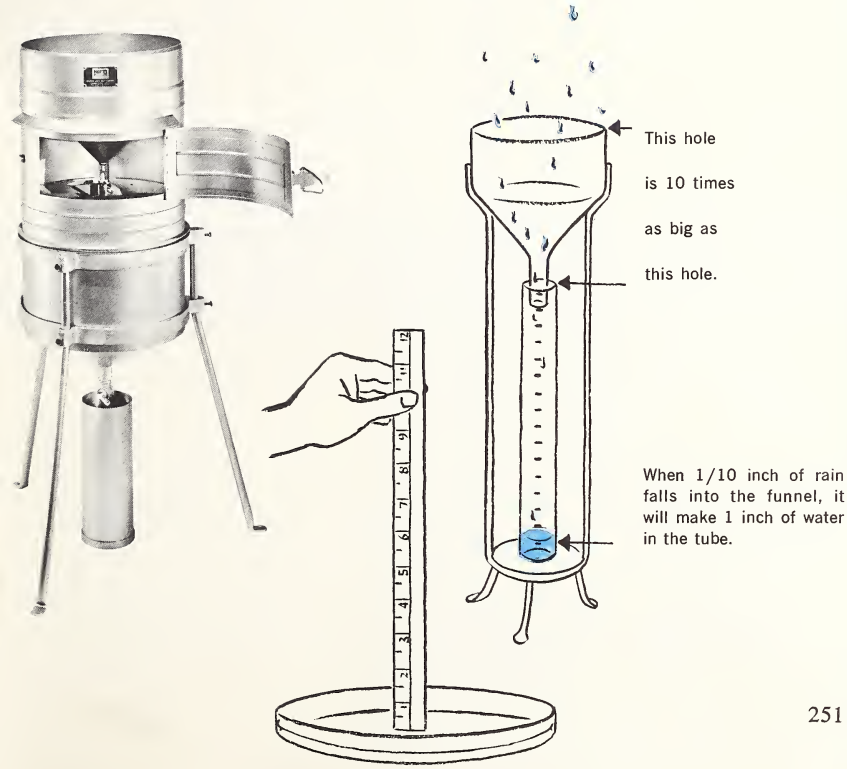
When the temperature of the air high above the earth is 32° F. or below, the moisture in the air forms snow. Snowflakes are bits of material formed in special patterns. How are all the patterns alike? How are they different?

Scientists can measure the amount of rain that falls. They do this with a *rain gauge*. You can make a simple rain gauge. Take a pan with straight sides and put it outside while rain is falling. Then, using a ruler, measure how deep the water is in the pan.

At weather stations there are rain gauges that measure very light rains. You can see one in the picture.

There are many reasons why we need to measure the amount of rain and snow that falls. What reasons can you think of?

Here you see the weatherman's rain gauge and one that you can make.



Be sure pupils understand why condensation is occurring. Warm air is hitting a cold surface, and the invisible water vapor is changed into visible water droplets. The temperature of the cold metal surface slows down the movement of the water vapor molecules, so that a large number of them collect into a visible droplet of water.

After the activity described on pages 248–249, which illustrates why clouds appear white, some children may point out that clouds can also appear gray. You might take time to explain here that the color of a cloud depends on its thickness, as well as its position in relation to the sun. If a thick cloud is at the same level as the sunlight, it will appear gray. If the sun is behind the cloud, it may appear dark gray, and may have a "silver" lining.

Here is a simple method of making a "cloud" in the classroom. (Another method is described on page 254 of the text.)

Light a match, blow it out, and drop it into the bottle so that its smoke rises. Then place an ice cube on the mouth of the bottle. A cloud will begin to form in the bottle under the ice cube. Why?

Discussion should reveal that the water vapor in the air condenses around the dust particles from the smoke, as the air near the ice cube cools. Point out to the children that clouds need nuclei for their formation. Water vapor particles will condense more readily around a bit of matter—dust, salt, even an electrically charged ion—than when there is no surface on which to condense. Relate this fact to the material on page 249.

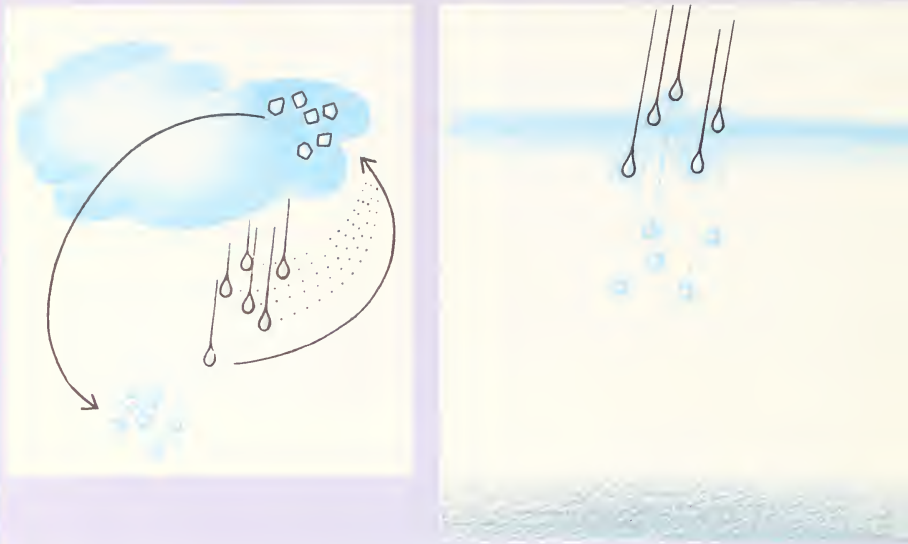
ADDITIONAL ACTIVITIES:

Have pupils make reports to the class on different methods of artificial rainmaking.

Leave a pan of hot water inside a bell jar for several minutes. After the air has become moist by evaporation, remove the pan. Evacuate the bell jar rapidly with a suction pump. Watch the air in the bell jar become foggy when it is cooled (by expansion) to the saturation point.

Background: Following are the answers to *Using What You Have Learned,* pages 254–255.

1. The capacity of a given amount of air for water vapor is decreased when the temperature drops. When the capacity is reduced below the actual vapor present, the excess vapor condenses on the



Read the text first. Then look at the pictures. Can you now explain, using the pictures, how hail and sleet are formed? What is the difference between the two?

Hail and Sleet

Sometimes frozen raindrops are blown back up into a cold layer of clouds. Other drops of very cold water freeze around the raindrops. Each time this happens, a new layer of ice is added. They get larger and larger and fall to the ground as hailstones. The diagram above, left, shows how this happens.

Sleet is formed when rain falls through air that is below freezing. The rain freezes into small bits of ice. The diagram above, right, shows this.

A Look at the Weather Scientist

We can tell many things about the weather just by our senses. We can tell when the wind is blowing, and when the air is still. We can tell when the air is cold, and when it is warm. We can see the clouds in the sky.

But just using his senses is not enough for the scientist. Like anyone else, he can see whether it is raining. But if he wants to know how much it has rained, he needs to take measurements.

In the same way, he measures and compares to find out more about the temperature of the air and the pressure of the air. He measures and compares to find out about the wind. He can measure how much rain or snow falls to the earth. He then compares these measurements with past measurements.

Weather scientists not only measure and compare weather conditions. They also keep careful records of their measurements and comparisons over the years. From these records they have found that certain kinds of weather usually come in the same order every time. Knowing this helps them tell what the weather will probably be tomorrow or the next day.

This weather station takes readings at sea. Why are such readings important?

smoke particles to form a cloud of water droplets. The cooling takes place when the air in the jar is expanded by pulling *up* on the rubber diaphragm.

2. The term a*neroid* has a Greek root meaning "not moist" or "not wet." It is used to describe instruments that do not use a liquid.

ADDITIONAL ACTIVITIES:

Trace development of Fahrenheit temperature scale. Find out how the points of 0°, 32°, and 212° were established.

Investigate radiosondes. These minature weather stations, carried high up into the atmosphere, are of great value in weather forecasting.

Find the hottest and coldest temperatures ever recorded on earth. What is the record high and low temperature for your town or city?

In what ways are weather satellites useful to the meteorologist in the process of weather prediction?

Investigate and report on the Beaufort scale of wind speed. The U. S. Weather Bureau uses the wind barb decimal system to denote wind speeds, which is a modification of the Beaufort scale.

Why are winds expressed in terms of nautical miles per hours?

Investigate and report on the sling psychrometer, the wet and dry bulb thermometer which is used to measure relative humidity.

How does the atmosphere act as an insulator? What radiations from the sun would harm us if the earth had no atmosphere?

The following table shows the monthly normal temperatures for three cities in the United States.

MONTHS	CITIES		
	Miami	New York	Anchorage
Jan.	68°	33°	13°
Feb.	69°	33°	19°
Mar.	71°	41°	25°
Apr.	74°	50°	35°
May	77°	61°	46°
June	80°	70°	54°
July	82°	75°	57°
Aug.	82°	73°	56°
Sept.	81°	67°	48°
Oct.	78°	57°	36°
Nov.	72°	46°	22°
Dec.	79°	36°	14°

Use the above table in answering the following questions.

Using What You Have Learned

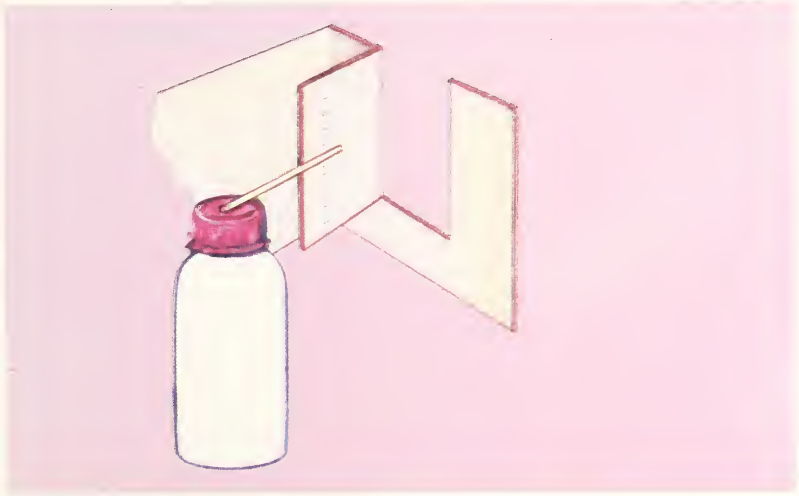
1. You can make a cloud in your classroom. You will need a large glass jar with a rubber cap. Some water and some smoke will also be necessary.

   To make your cloud, you put the water into the glass jar. Then put in the smoke. Cover the jar with the rubber top and then pull it up. When you do this, a cloud will suddenly appear. Can you explain why this happens?

2. You can make a barometer. The kind you will make is called an aneroid barometer. Can you find out why it is called by this name? Stretch a rubber balloon over the top of a glass jar and put a rubber band around the balloon to hold it tight. Glue a drinking straw to the center of the balloon top. This is your pointer.

If the air pressure on the outside of the jar becomes greater than that inside the jar, the balloon will be pushed into the jar and the point of the straw will rise. If the pressure of the air on the outside of the jar becomes less, the air inside will push the balloon up, and the point of the straw will go down.

To make a scale for your barometer, draw a line on a piece of paper. Put the paper so that the pointer will move up and down the line. At the same time each day, mark the spot the pointer points to. Keep a record of the changes in air pressure. Changing air pressure usually means changing weather. Your barometer will not be as exact as one you might buy. Still, it will give you some idea of how much the air pressure can change from day to day.



1. What is the March temperature in Miami?

2. What is the September temperature in New York?

3. In which city is the June temperature 54 degrees?

4. In which city are the temperatures lowest for every month in the year? Does the table tell you why?

5. In which city are the temperatures highest for every month of the year? Does the table tell you why?

6. During which month are the temperatures highest in all three cities? Does the table tell you why?

7. During which month are the temperatures lowest in all three cities? Does the table tell you why?

8. Does the table tell you which city gets the most snow in the winter?

9. What is the difference between the lowest and highest temperature in each of the cities?

10. In which city is the difference greatest? In which city is it least?

TEACHING SUGGESTIONS
(pp. 256–257)

Background: These two pages constitute a review of the concepts and terminology introduced in this unit.

What You Have Learned: This is a summary of the entire unit, with new words in boldface type.

Checklist of Science Words: Remind the pupils that there is a *Dictionary of Science Words* on pages 318–325. They should consult this dictionary whenever they are unsure of the precise meaning of a word.

WHAT YOU KNOW ABOUT
Weather in Your Life

What You Have Learned

Telling the weather ahead of time is known as **forecasting** the weather. Weather forcasting is done by weather scientists working in **weather stations** throughout the world. Weather scientists know about the changes in **temperature, air pressure,** and **water vapor** in the air, and what causes these changes.

One of the reasons weather is different in various places is that sunlight heats some surfaces faster than others.

The speed and the direction of air often tell weather scientists what sort of weather to expect. An **anemometer** is used to find wind speed, and a **wind vane** is used to find the direction of the wind. A **mercury barometer** is used to measure air pressure. It is read by noting how many inches the mercury moves up or down in the tube. A change in pressure usually indicates that there will be a change in the weather.

Most important, weather scientists keep accurate records of all their readings. They use these readings to make comparisons. The comparisons help them to forecast the weather.

Checklist of Science Words

Here are some science words you read about in this unit. Can you tell what you have learned about each one?

anemometer	evaporation	thermometer
barometer	forecast	water vapor
condensation	molecules	weather station

Complete the Sentence

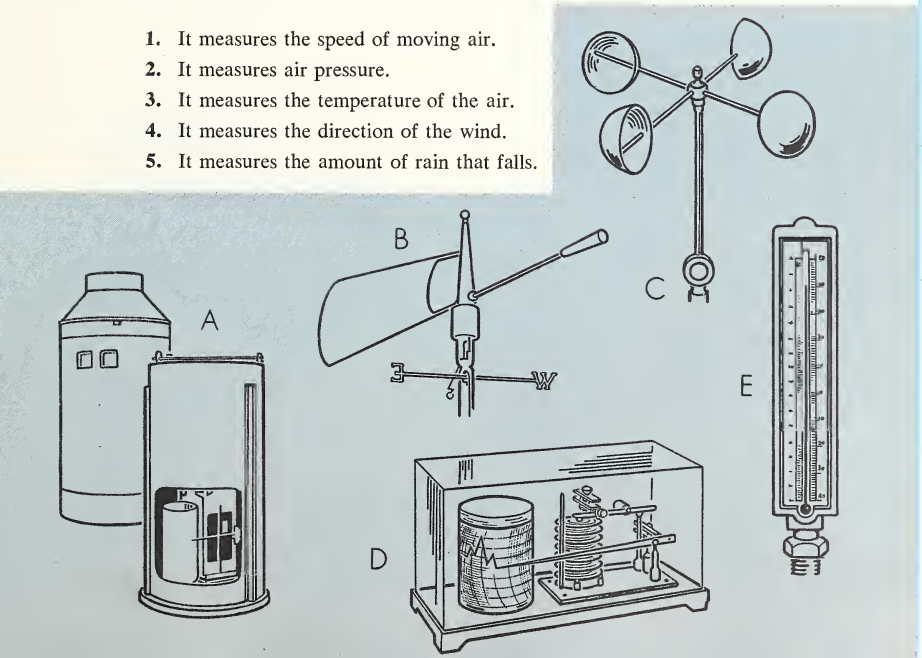
Write the numbers 1 to 4 in your notebook. Next to each number, write the word *faster* or *slower* to make the sentence correct.

1. The land heats up ____?____ than the water.
2. Molecules of cold air move ____?____ than molecules of warm air.
3. Light-colored objects usually heat up ____?____ than dark-colored objects.
4. As water is heated, the molecules move ____?____.

Find the Picture

Write the numbers 1 to 5 in your notebook. Next to each number, write the letter that tells which picture the sentence is about.

1. It measures the speed of moving air.
2. It measures air pressure.
3. It measures the temperature of the air.
4. It measures the direction of the wind.
5. It measures the amount of rain that falls.



Complete the Sentence:

1. faster
2. slower
3. slower
4. faster

Find the Picture:

1. C
2. D
3. E
4. B
5. A

TEACHING SUGGESTIONS
(pp. 258–259)

Background: These pages reinforce the concepts presented in the unit by suggesting activities that extend the pupil's ability to apply the learnings derived from the unit.

What Are the Words?

1. Water vapor
2. Molecules
3. Evaporation
4. Barometer
5. Thermometer
6. Condensation
7. Forecast

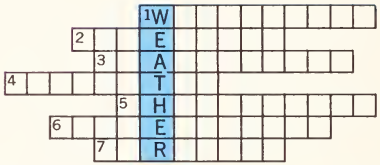
YOU CAN LEARN MORE ABOUT

Weather in Your Life

What Are the Words?

Write the words in your notebook.

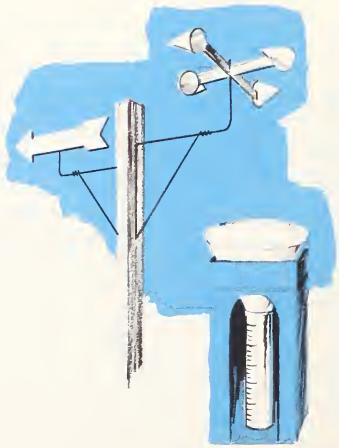
1. What water in the air is called.
2. The very small parts that the air is made of.
3. The changing of liquid water to water vapor.
4. It measures air pressure.
5. It measures air temperature.
6. What water vapor changing to a liquid is called.
7. To tell the weather ahead of time.



Build Your Own Weather Station

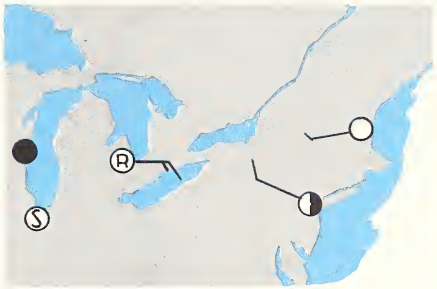
You can make your own records of the weather. You will need instruments to help you. To start your weather station, you can use the barometer you made. (Look on p. 254.) You can learn how to build other instruments if you read *Everyday Weather and How It Works* by Herman Schneider.

Make a record of your observations twice a day. Then see if you can forecast the weather. Compare your forecast with that of the weatherman.



How to Read a Weather Map

Below you can see some of the symbols that are used on a weather map and what they mean. Look at the map and see if you can tell what kind of day it is and how windy it is in the cities shown.



Clear	Calm
Partly cloudy	3-8 mph
Cloudy	9-14 mph
R Rain	15-20 mph
S Snow	21-25 mph

You Can Read

1. *Man and Weather Satellites* by Walt Disney. How satellites will aid in forecasting the weather.
2. *Exploring the Air Ocean* by Frank H. Forrester. How man learned about the weather.
3. *Weathercraft* by Athelstan F. Spilhaus. How to make and operate weather instruments.
4. *Let's Go to a Weather Station* by Louis Wolfe. The story of a trip to a local weather station.
5. *The First Book of Weather* by Rose Wyler. Tells what causes weather. Also, many experiments.

You Can Read: Pupils can read the following:

Exploring the Weather, by Roy A. Gallant (Doubleday, 1957).

Seeing the Earth from Space, by Irving Adler (John Day, 1962).

1001 Questions Answered About the Weather, by Frank H. Forrester (Dodd, Mead, 1957).

Between Earth and Space, by Clyde Orr (Macmillan, 1959).

Everyday Weather and How It Works, by Herman Schneider (McGraw, 1961).

For teacher:

The Nature of Violent Storms, by Louis J. Battan (Doubleday, 1961).

Radar Observes the Weather, by Louis J. Battan (Doubleday, 1962).

Modern Earth Science, by Ramsey and Burchley (Holt, 1965).

Key Concept 1. Events in the natural environment happen in an orderly rather than a haphazard way; man searches for laws to explain this order by observing, hypothesizing, checking his ideas, and rejecting those which do not square with reality.

Key Concept 10. Man has changed and continues to change the natural environment; but because he is often ignorant of long-range consequences, his actions may have harmful effects for himself and for other living organisms.

CONCEPTS:

1. All accidents have a cause.
2. Safety rules help to prevent accidents.
3. Traffic signs and traffic signals prevent many accidents.
4. Polluted water is unsafe water.
5. Water becomes polluted in many ways; however, there are methods of preventing it.
6. There are various ways in which impure water can be made safe for drinking.
7. By following safety rules swimming accidents can be avoided.
8. Fuel, oxygen, and kindling temperature are necessary before a fire will burn; by controlling any one of these, fires can be prevented or extinguished.

9

Other concepts appear under "Learning to Be Developed" in each lesson found in the Teaching Suggestions.

Safety and Science

How Do Accidents Happen?

Bicycle Safety

Water Safety

Fire Safety

Safety in Science

PROCESSES:

- Questioning—Pages 262, 263, 279, 288.
- Observing—268, 269, 270, 271, 274, 275, 276, 277, 278, 281, 282, 283, 286, 287, 289, 290, 293, 294, 295, 296, 297, 298, 299, 300, 301, 302, 303, 304, 305, 306, 307, 308, 310, 311.
- Experimenting—271, 282, 284, 289, 290, 293.
- Comparing—264, 265, 271, 274, 275, 282, 283, 284, 289, 290, 293, 294, 295, 296, 297.
- Inferring—265, 271, 274, 276, 277, 282, 284, 286, 287, 289, 290, 293, 294, 295, 298, 299, 300, 301, 302, 303, 304, 305, 306, 307, 308, 313.
- Measuring—264.
- Classifying—264, 271, 274.
- Selecting—262, 266, 309, 312, 314.
- Communicating—262, 263, 309.
- Demonstrating—271, 282, 284, 290, 293.
- Explaining—263, 271, 274, 275, 276, 277, 281, 282, 284, 286, 289, 290, 293, 309, 310, 311, 313, 314.
- Hypothesizing or Speculating—284, 285.

TEACHING SUGGESTIONS
(pp. 262–265)

● **LESSON:** How do accidents happen?

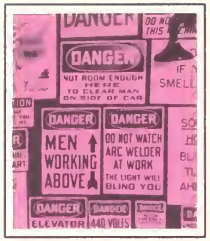
Background: Children may be interested in finding out about accidents that happen outside of their own class group. Compare the information collected by the National Safety Council with that obtained by the class in this lesson. For example: More accidents causing injury happen in the home than anywhere else; in a recent year 4,100,000 injuries including 27,500 deaths were caused by home accidents. More accidents causing death happen on the highway than anywhere else; in a recent year 36,000 deaths resulted from auto accidents, and 1,250,000 nonfatal injuries occurred. More accidents of all types, except drowning, happen among children from birth to four years of age, than among those from five to fourteen. Compare these findings with those of your class, as well as with accident surveys of other fourth graders.

Learnings to Be Developed:

Most accidents can be avoided.

We try to prevent accidents by eliminating their cause.

To determine the cause of acci-



In the gymnasium of one school, a sign reads: "Sneakers Must Be Worn While Playing in the Gym." Mr. Brownlee, the teacher in charge, makes sure that this rule is obeyed, because he knows that pupils with leather-soled shoes may slip on the gym floor and get hurt. Mr. Brownlee wants to avoid accidents.

How Do Accidents Happen?

Each year, the National Safety Council publishes a report called *Accident Facts*. The report tells about the kinds of accidents people have and where these accidents happen. It is important to know these facts. They are useful in finding ways to reduce accidents. But there are other things we need to know to prevent accidents. We must know *why* accidents happen. Then we can decide what we must do to remove the causes of accidents.

Children have accidents most often when they are playing. You can make your playtime safer if you follow three steps.

The first step is to *find out what causes accidents.* The second step is to *plan ways to avoid these causes.* The third step is to *use your plan to make your playtime a safer time.*

Can you make up a plan to prevent some of the accidents that might happen while playing? If you are careful during playtime, you are less likely to have accidents.

Children's Playtime

Where do you play? What do you play? What things do you use in your play?

You know what your answers to these questions are. But do you know what your classmates would answer? You can find out by making a survey.

Have each pupil write his or her name at the top of a sheet of paper. Ask each pupil to answer all three questions. More than one answer can be given for each question.

After everyone has finished writing the answers, the class should choose a

committee to write down the results. The committee should make a checklist like the one on page 264.

Have a member of the committee write each of the answers from the first pupil's paper on a separate final sheet of paper. This sheet is called the *master list*. After each of the answers from the first pupil's paper is written on the master list, a mark, |, is made to show that the first pupil listed it. Now read the answers from the next pupil's paper. If an answer appears on the second paper that has already been put on the master list, another mark, |, should be made after it. There are now two marks after this answer on the master list. If a different answer appears on the second paper, it should be written on the master list and a mark, |, made after it. The committee should add all the answers from everyone's paper to this list in the same way.

These are just a few of the many safety signs used by one large company. How do such signs aid the people who work for this company? Have you ever seen such signs?

DANGER
CRANE OVERHEAD
CAUTION MEN WORKING OVERHEAD
ONLY AUTHORIZED PERSONS PERMITTED TO OPERATE EQUIPMENT IN SHOP
SOUND HORN BLIND TURN AHEAD
DANGER
ALARM IF YOU SMELL FUMES
DO NOT ENTER WITHOUT SAFETY GLASSES
NEVER RUN PUMP DRY
MEN WELDING DO NOT LOOK AT ARC
CAUTION DO NOT ENTER WHILE MACHINERY IS IN MOTION
FOR SAFETYS SAKE WALK UP & DOWN STAIRS
DANGER NO OPEN LIGHTS
NO SMOKING ALLOWED
DANGER EXPLOSIVE CHEMICALS STORED HERE
DANGER MEN WORKING ABOVE
DO NOT WATCH ARC WELDER AT WORK THE LIGHT WILL BLIND YOU
SOUND HORN BLIND TURN AHEAD
DANGER
CAUTION CONSTRUCTION WORK AHEAD
ACID HAZARD WEAR HAT AND GOGGLES
DANGER ELEVATOR SHAFT
DANGER 440 VOLTS
DO NOT ENTER WITHOUT SAFETY GLASSES
MEN WELDING DO NOT LOOK AT ARC
DO NOT USE THIS MACHINE WITHOUT PROPER AUTHORIZATION
SAFETYS SAKE WALK & DOWN STAIRS
GOOD HOUSEKEEPING KEYNOTE SAFETY CLEANLINESS ORDER A PLACE FOR EVERYTHING EVERYTHING IN ITS PLACE
DANGER KEEP FROM UNDER CRANE LOADS
CAUTION MEN WORKING OVERHEAD
KEEP GATES CLOSED
CAUTION ELECTRIC TRUCKS GO SLOW
CAUTION HIGHLY FLAMMABLE
NO SMOKING

dents, a scientific survey can be helpful.

Developing the Lesson: Begin with a discussion of the word "accident." You will undoubtedly find that it means different things to different pupils. Have pupils consult a dictionary to define the term, and settle on a good working definition for use in this unit.

Point out to your class that one of the first things a scientist does when he has a problem is to gather whatever available information he can find about that problem. The problem in this lesson is: "How can accidents to children be prevented?" Ask the class what information is needed. List on the board such questions as: Where do most accidents happen? Do more accidents happen during certain months? What different kinds of accidents occur during different seasons? Do boys have more accidents than girls? Do more accidents happen to younger children than to older children?

Ask your pupils why answers to these questions would help in solving the problem. Discuss what other kinds of information might be helpful.

The question should arise as to how children can obtain informa-

tion about accidents. Hopefully, someone will suggest a survey. Discuss the value of conducting a survey of accidents that have happened to children in your class since they started school. Now turn to the material on the survey, in the text.

As a result of the class survey, many suggestions will be obtained for preventing accidents. "Removing hazards" might be one large group. Pupils can be presented with a large drawing showing many hazards inside a living room or kitchen. These might include bare electrical wires, objects which can be easily tipped over or tripped over, objects which might cause fire, rug edges on which one could slip, etc. Ask pupils to identify the danger spots and suggest ways of removing them.

MASTER LIST OF PLAY ACTIVITIES OF MISS DALE'S CLASS

1. Where we play:

swimming pool	15
ice skating rinks or ponds	10
campgrounds	3
sidewalks	11
vacant lots	5
backyard	15
inside my home	22
in the school playground	22

2. What we play:

swimming	11
ice skating	10
camping	3
riding bicycles	10
baseball	5
jumping rope	15
checkers	5
roller skating	6

3. Things we play with or on:

water	15
ice	10
camp equipment	3
bicycles	10
baseball and bat	5
jump rope	15
checker set	5
roller skates	6

The Causes of Accidents

Look again at the marks after the answers of Miss Dale's class. How is each fifth mark made? Why is it made this way? What do the numbers on the right tell us?

Not all the play activities of Miss Dale's class are shown. Your survey might show many more different kinds of activities for your class. What is your favorite play activity?

Have you ever had an accident? What is an accident?

An accident is a mishap. Usually we do not expect an accident to happen. It just happens! Do you think that every accident has a cause?

Think of an accident that has happened to you. Was there a cause for it? How could you have prevented this accident? Make up a rule about the way to prevent an accident.

Using What You Have Learned

Look over your survey. What things on your list do you think might cause accidents? From a survey of children's accidents in one large state, the following things were found to be related to accidents:

1. Sports equipment (baseballs and bats)
2. Bicycles and tricycles
3. Toys (chemistry sets, electric stoves, and electric irons)
4. Playground equipment (swings and seesaws)
5. Sharp-edged tools (chisels and screwdrivers)
6. Children's cars or wagons
7. Broken glass and tin cans
8. Animals (cats and dogs)

Have you ever been injured by any of these things? Children can be injured in different ways by accidents. Make another survey to find out how the boys and girls of your class were injured in accidents.

"Avoiding falling accidents" might be another large group. Discuss how such accidents happen. Point out that a person's center of gravity may be shifted too far away from his support. This can occur, for example, when you reach too far while on a ladder, to obtain an object in a far corner of a closet.

Ask pupils in what way a person's feelings might cause him to have an accident. A person who is angry, for example, might take chances which he would not ordinarily take. A person who is very competitive might cause an automobile accident, by not allowing another car to pass him on the road.

Follow-Up: Conduct a discussion on how the eight things listed in *Using What You Have Learned* on page 265 could cause accidents, and how they could be prevented.

ADDITIONAL ACTIVITIES:

Have a committee survey the school building, gymnasium, and other playground areas, and report any defective equipment that could cause accidents.

Usually the school nurse keeps a regular list of all accidents for the past year. Have her give a talk to the class on how the recurring ones could be avoided.

TEACHING SUGGESTIONS
(pp. 266–269)

LESSON: What safety rules will help prevent bicycle accidents?

Background: Except in large cities, many children come to school by bicycle. But, as the material on these pages indicates, children don't always travel safely. The school is usually the only community agency in a position to stress bicycle safety and you should emphasize it strongly in this lesson. Point out that there is an increasing number of cyclists each year, and there is also an increasing number of trucks and automobiles on the highways.

Learnings to Be Developed:

Bicycles are the cause of many accidents.

Bicycle riding can be safe if some simple rules are followed.

Developing the Lesson: Introduce the pathfinder, William L. Potts, as one of many public officials to whom safety on the roads was a life work. Find information about your own local traffic official or commissioner of public safety, and use him to exemplify the seriousness of road safety.

Perhaps the most striking advance in traffic control with which your pupils may be familiar is the auto-

Bicycle Safety

How many pupils in your class have bicycles? How many have had accidents witn them? What caused the accidents?

The National Safety Council estimated that bicycle accidents in the United States in 1964 killed about 650 people and injured 35,000 other people. Children between the ages of 5 and 14 accounted for two thirds of the people killed in bicycle accidents. It is easy to see from these numbers that bicycles can be very dangerous when people are not careful.

Collisions with cars, buses, and trucks were the most common bicycle accidents. Falling off bicycles, riding into trees and fences, riding into people, and racing were other causes of bicycle accidents. Still other accidents happened because a rider came out of a driveway, or entered the street from between parked cars, without looking.

Were you ever in a bicycle accident because you did one of these careless things? If you were, or if you know someone who was, you know how serious these accidents can be.

William Potts made the first four-way traffic-signal tower, shown on the left.

PATHFINDERS IN SCIENCE

William L. Potts

(1893–1956) United States

Imagine what it would be like if there were no traffic lights in your town. How would you know when to cross the street? How would automobiles travel safely along the streets?

As a member of the Detroit Police Department and as a traffic engineer, William L. Potts was faced with just such a problem.

A bicycle safety program in action.

Because of such surveys, rules like those on pages 268 and 269 were made. Can you think of the reason for each rule? Perhaps you can have a class discussion on the reasons for these rules.

Some schools have bicycle safety programs. In these school safety programs, young people learn how to use their bicycles safely. They find out what causes most bicycle accidents. Then they learn how to avoid the most common kinds of accidents. These school safety programs help greatly to reduce the number of serious bicycle accidents. Can you plan a bicycle safety program for your school?

In 1920, Mr. Potts set up the world's first four-way traffic-signal tower at Woodward and Michigan Avenues in Detroit, Michigan. To get attention, he chose the tallest policemen in the department to operate the tower. The tower had twelve lamps — three lamps on each of the four sides of the tower. One year later, in 1921, Mr. Potts saw another of his dreams come true. The first automatic traffic signal was built.

More than forty years have passed, and traffic signals have changed a great deal. But the original idea of traffic lights developed by William Potts is still being used.

William Potts made many important changes in motoring safety. He helped dozens of Michigan communities solve their traffic problems. He is also known as one of the first men to try using two-way radios in police cars. Now nearly every police car has a two-way radio.

"Old Mr. Traffic Tower," as Mr. Potts was respectfully and affectionately named by his friends of the Detroit Police Department, did much to make our world a safer place in which to live.

matic control of a series of traffic lights at a complicated intersection. If there is such an intersection close to the school, one traffic light will be found that has a control box fastened to it. The controls in the box control the sequence and timing with which the lights change. By listening to the box, the ticking of the timing mechanism, and the slapping of the control relays as they open or close, the light circuits can be heard. Some of the pupils may be interested in puzzling out the exact sequence with which traffic in the various streets is made to stop and go, and the length of each interval. As traffic conditions change during the day, these intervals will also change to help the traffic flow efficiently.

The pupils may also be familiar with the way that a series of lights will change in sequence to control the flow of traffic along a major road. The timing of each light in relation to the other traffic lights is accomplished separately. In other words, the end result—the smooth flow of traffic—is done piecemeal. This practice will give way within the near future to networks of traffic lights covering large areas of cities that are interconnected with each other and also with a central computer. It

will sense the amount of traffic on all the major streets and alter the timing of the traffic lights automatically to make the overall flow of traffic as fast and as smooth as possible. Toronto, Ontario, already has such a system installed, and many American cities are beginning to install computer-controlled systems.

Discuss the bicycle safety rules on pages 268–269. Every cyclist should know these rules. Dramatize the rules by having a playground demonstration of the major violations and their consequences. If possible, get the assistance of the local police department in putting on a safe-riding rodeo on your school grounds.

Ask pupils to suggest some additional rules which might apply under certain circumstances. These might include the following:

Games such as bike-hockey or bike-polo should not be played except under supervised conditions.

When riding on heavily traveled streets, do not weave back and forth.

Use bicycle paths wherever they have been provided. Do not ride on footpaths.

BICYCLE SAFETY RULES

1. Ride your bicycle in the same direction as the traffic is moving.
2. Ride only as fast as safety permits. Ride slowly on crowded or slippery streets.
3. Be careful not to zigzag in and out of moving traffic.
4. Give signals before making turns, and only after looking around to make sure nothing is coming your way.
5. Watch out for people in parked cars who may suddenly open one of the doors.

6. Look carefully before coming out of driveways or from between parked cars.

7. Watch out for parked cars that might suddenly speed into your traffic lane without warning.

8. Never race.

9. If you must ride at night, be sure your bicycle lights are working.

10. Never ride with another person on a bicycle unless the bicycle is built for two.

11. Always ride single file when you are riding with others — never two abreast.

12. Be careful! Ride safely!

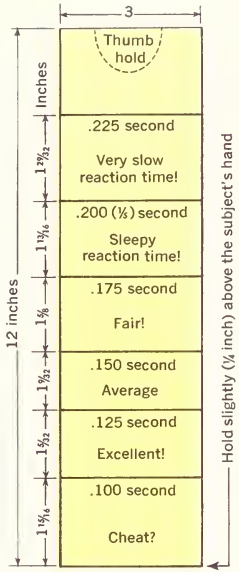
Follow-Up: Demonstrate the time it takes to stop a bicycle. Take the pupils to the playground and mark a chalk line on the ground. Have a child ride a bicycle slowly up to the line and apply the brakes when he touches it with his front wheel. Measure the distance before the bicycle actually stops. Repeat this procedure with a faster rider. Comparison of the stopping distances of the two speeds should indicate why faster speeds cause more accidents.

You might bring to the attention of the class the fact that an automobile going 20 m.p.h. needs at least 30 feet to stop, even with the best of brakes and tires. At 40 m.p.h., it would need 120 feet.

ADDITIONAL ACTIVITIES:

Students can test reaction times. Divide the class into pairs. Provide each pair with a paper clip and a yardstick. Have one pupil hold the clip 12 inches off the floor, an inch or two in front of his partner's foot. When the clip is dropped, the second pupil should try to make it land on the toe of his shoe by moving his foot forward. After each unsuccessful trial, move the clip higher until the pupil is successful. Falling times of the clip are approximately:

12 inches	¼ second
30 inches	⅗ second
48 inches	½ second

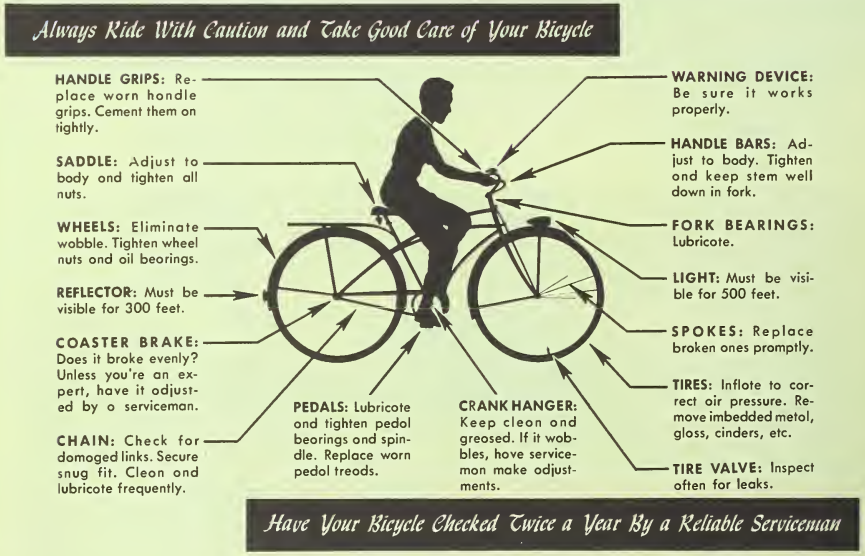


Another experiment is one used by Transit Casualty Co. Follow diagram: cut a stiff piece of oaktag or cardboard 12 inches long and 3 inches wide. Let one pupil hold this "test timer" at the point marked, between thumb and forefinger, vertical to the floor. The pupil being tested should keep his thumb and forefinger apart, so the timer can slip between them, and should be told to grasp the timer as quickly as possible when it is dropped. The point at which the timer is grasped shows the approximate reaction time of the subject.

Check Your Bicycle for Safety

In order to ride your bicycle safely, you must do more than obey all safety rules. You must check your bicycle regularly to make sure it is always in good condition. Study the picture below. It shows all the places that you should check on your bicycle. Remember that a small repair can often prevent a big accident.

A good safety measure for a person who uses his bicycle after dark is to have the bicycle painted a light color instead of a dark color. If you did the experiment on pages 14 and 15, you saw how different colors reflect different amounts of light. The experiment on the next page will also help you to understand why some colors are safer to wear at night.


Always Ride With Caution and Take Good Care of Your Bicycle
HANDLE GRIPS: Replace worn handle grips. Cement them on tightly.
SADDLE: Adjust to body and tighten all nuts.
WHEELS: Eliminate wobble. Tighten wheel nuts and oil bearings.
REFLECTOR: Must be visible for 300 feet.
COASTER BRAKE: Does it broke evenly? Unless you're an expert, have it adjusted by a serviceman.
CHAIN: Check for domaged links. Secure snug fit. Cleon and lubricote frequently.
PEDALS: Lubricote and tighten pedal bearings and spindle. Replace worn pedal treads.
CRANK HANGER: Keep cleon and greased. If it wobbles, hove servicemon make adjustments.
WARNING DEVICE: Be sure it works properly.
HANDLE BARS: Adjust to body. Tighten and keep stem well down in fork.
FORK BEARINGS: Lubricote.
LIGHT: Must be visible for 500 feet.
SPOKES: Replace broken ones promptly.
TIRES: Inflote to correct oir pressure. Remove imbedded metol, gloss, cinders, etc.
TIRE VALVE: Inspect often for leaks.
Have Your Bicycle Checked Twice a Year By a Reliable Serviceman

Which Colors Are Safest to Wear at Night?

What You Will Need

flashlight colored paper (several sheets)

How You Can Find Out

1. The sheets of paper stand for the bicycle riders.
2. The flashlight stands for an automobile headlight.
3. Darken your classroom as much as possible.
4. Shine a flashlight on a dark sheet of paper.
5. Then shine the flashlight on a light piece of paper.
6. Compare several sheets of paper to see which color can be seen most easily.

Questions to Think About

1. Why is it safer to wear light-colored clothing when you are bicycling at night?
2. Why should you make sure that your bicycle has a taillight or a reflector?
3. What colors do policemen wear at night so that they can easily be seen?
4. Which of these colors do you think would be best for you to wear when you are bicycling at night?

blue	black	white	yellow
red	green	orange	purple

5. What colors do automobile makers use for different lights on a car to make them do their job at night? Why do you think car makers choose these colors?
6. Have you ever seen an airport at night? What color are the lights that are used along the runways? Why do you think this color is used?
7. White is the best color to wear for safety at night. What is the worst?

TEACHING SUGGESTIONS

(pp. 271–272)

LESSON: Which colors are safest to wear at night?

Learnings to Be Developed:

Light colors reflect light to the eyes of observers.

Light colors should be worn when riding or walking out of doors at night.

White and yellow reflect more light than darker colors.

Developing the Lesson: Have children recall the ideas learned in Unit 7, "Light and Sight," and emphasize that we only see the light that is *reflected* to our eyes. This means it is necessary to wear clothes that have a high reflecting color in order to be seen under conditions of low illumination.

If you use a photographer's light meter, your comparisons in this experiment will be less subjective and more reliable.

Background: Following are the answers to *Questions to Think About*, page 271.

1. The reflected light from oncoming cars and street lights is more noticed by drivers.

2. A bicycle has very little width and is hardly noticeable from the rear or front. A reflector will concentrate the headlight rays of oncoming vehicles and send them back to the driver, thus warning him of a possible hazard ahead.

3. White belts with reflectors are frequently worn by police on night traffic duty. Experiments with fluorescent paint and dyes have shown that these are excellent for the coating of policemen's and firemen's raincoats and outerwear.

4. White, orange, and yellow are the best of those listed.

5. White is used for headlamps, to light up the area in front of the car. Amber lights are used in fog because they do not scatter and reflect back at the driver. Red is used on any device that requires the attention of other drivers such as turning signals, flashing emergency lights, and brake lights.

6. Amber—first thousand feet of approach; green—end of runway; white—side lights.

7. Black absorbs nearly all light and reflects practically none.

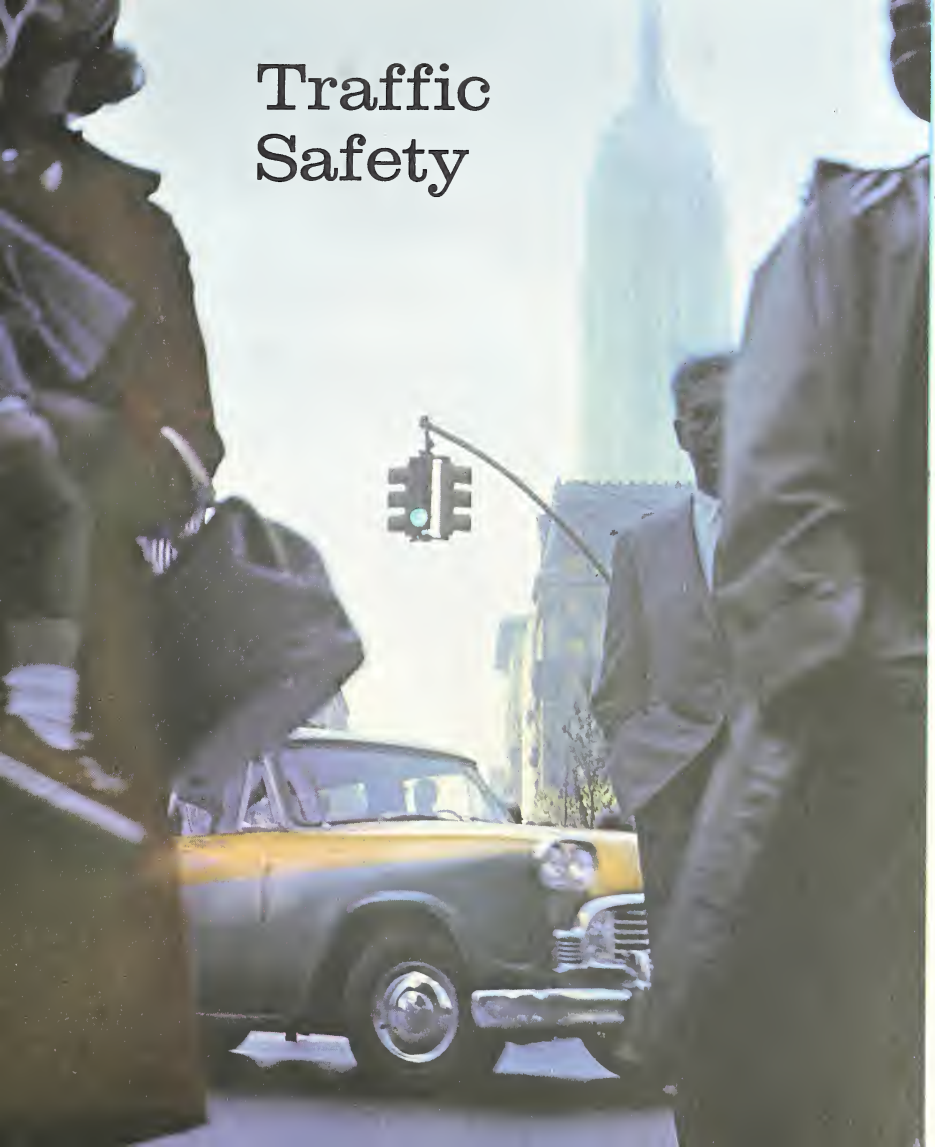
An automobile driver sees both you and your bicycle at night because the light from his headlights is reflected back to him from you and your bicycle. Light colors, such as white and yellow, reflect more light than darker colors, such as black and brown. For this reason, it is safer to wear light-colored clothing for riding at night. You should also be sure your bicycle has a red taillight or a reflector, as well as a headlight. And most important, ride at night only if it is really necessary.

ABOUT "TRAFFIC SAFETY"

Knowing about traffic safety is important for everyone. But it is most important for boys and girls who have not been crossing the streets by themselves or who have not been riding bicyles very long. One of the best ways to find out about traffic safety is by reading your schoolbooks and listening to your teacher and parents.

In some communities, the police department has a special safety education group, which, among its other duties, visits schools to talk about and demonstrate traffic safety. The New York City Police Department has specially trained policemen who do this. You will now see and read about a safety demonstration that took place at an elementary school.

Traffic Safety



TEACHING SUGGESTIONS
(pp. 272–279)

LESSON: What can we learn about safety from a police department demonstration of traffic safety rules?

Learnings to Be Developed:

Children should know the safe way to behave on the street.

Local police traffic rules apply to walkers as well as to drivers.

Traffic signs have shapes that are meaningful.

Developing the Lesson: The ideal way to present the information in this lesson is to have the local police department demonstrate the activities illustrated and then use the picture story as a review. If a live demonstration is not possible, go over the pages of the text with the children, and thoroughly discuss the illustrations and captions.

Try some classroom experiments to test the need for various safety precautions. Using a toy truck and a wooden block, demonstrate why it is safer to sit than to stand in a car or bus. When the center of

gravity is nearer the ground, there is less likelihood of tripping or falling.

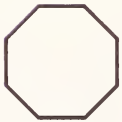
To illustrate the effects of a heavy load versus a light load in a moving vehicle, place the toy truck on an inclined plank and allow it to roll down. Record how far it traveled. Now place the wooden block in the truck, and allow it to roll down again. Again record the distance it went and compare. Pupils will see that both speed and weight are factors in stopping a moving vehicle.

Discuss some other factors concerned with stopping a moving vehicle. Have a child who is wearing leather-soled shoes walk quickly on a smooth floor and attempt to slide to a stop. Measure his stopping distance. Now have a child with rubber-soled shoes repeat the demonstration. Compare the distances it took each child to reach a complete stop. Relate this to the condition of automobile (or bicycle) tires and to the relative smoothness of a road.

Remind the class of the reaction-time tests they took in the previous lesson. Ask the question:

Officer Washington talks to the pupils about traffic safety. He begins by having a policeman hold up different traffic signs.

Officer Washington points to the backs of the signs and asks who can identify the signs from their shapes and designs. Why is it important to be able to tell traffic signs from their shapes? Can you tell what the signs mean by looking at their shapes?



This sign has eight sides. It tells the motorist to come to a complete stop and not move forward until he is sure that it is safe.

This four-sided sign tells us there is a school crossing. There are two such signs used. One is square, and the other is diamond shaped. Which kind do you have in your community?

This is a yield-right-of-way sign, which means that the motorist must give the other traffic the right of way. All these signs are for motorists. But it is just as important for you to know about them. Can you tell why?

Cut out signs like these and have your pupils identify their meanings from their shapes.

Here's how you signal a right turn . . .

signal a left turn . . .

The policeman is pointing to a headlight and taillight on the bicycle.

Why must you have these lights on your bicycle if you ride at night?

Officer Washington tells the boys and girls that more youngsters are injured crossing in the middle of the block than in any other kind of accident.

A motorist gives certain signals when he is stopping his car, making a right-hand turn, or turning to the left. If you ride a bicycle, you must also use signals. Can you tell why it is important for you to do so?

Practice hand directions in class.

. . . signal a stop.

- *Why can't the driver of an automobile or bicycle put on the brakes as soon as he sees danger?* (Because the danger signal must flash to his brain, be recognized, and come back to his muscles for him to react.)

Follow-Up: Have the children list safety rules for pedestrians. The American Automobile Association gives the following:

Look carefully in all directions before crossing.

Never step into a street between parked cars.

Never cross a street by weaving between moving cars.

Never cross a street by weaving between stopped cars.

Cross streets only at intersections.

Watch for cars that are turning, especially cars making left turns.

Obey traffic signals. Cross only on "Walk" or on a green light.

Walk on the sidewalk. Where there are no walks, face oncoming traffic. This means walking on the left.

Follow the directions of crossing guards or police.

ADDITIONAL ACTIVITIES:

Find out if the local police department has an accident-prevention unit or a safety-education unit. If they do, find out if they have special programs for schools.

Have members of the class write a play showing the reason for one particular safety rule and act out the play. Perhaps they can show it to another class.

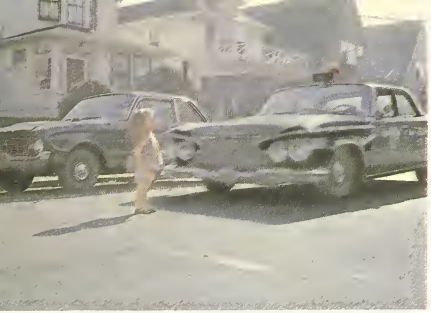
Make a list of danger spots around the school that are possible traffic hazards (high hedges, curves, trees, bushes, etc.). Describe what could be done to make them safer.

Many schools have drills in which the safety escape features of the school bus are explained. If your school does not have such a drill, let the class devise one.

In 1964 in New York City, 2,382 boys and girls between the ages of 5 and 10 were injured crossing in the middle of the block instead of at the corner. Let's see what happens when you cross from between parked cars in the middle of a block. The policemen pick Laura, an average-sized fourth grader, to assist them. Laura and Officer Egan will step off the curb into the street.

The police car coming down the street will stop when the driver first sees Laura. See how close the police car is to Laura.

Now a doll is put in the same place Laura was standing. This time the police car will be driven at 20 miles per hour. The policeman will put his foot down on the brake pedal of the car when he sees the doll.



The policeman puts the brakes on. But the car hits the doll! Why did this happen? The police car traveled a distance of 43 feet from the time the policeman observed the doll and applied the brakes.

You now see that a car cannot stop "on a dime." If you cross from between parked cars, the driver of the car may see you, but he may not be able to stop in time.

After seeing this demonstration, all the boys and girls promised never to cross mid-block, but only at the corners and only when they have a green light.

Take a trip to a high school industrial arts shop or auto shop, and have the teacher explain the safety precautions built into an automobile. Perhaps a local automobile showroom would provide such a demonstration for the class.

Discuss the safety values of lap-shoulder seat belts, padded dashboards, dual brakes, and four-way warning lights in automobiles.

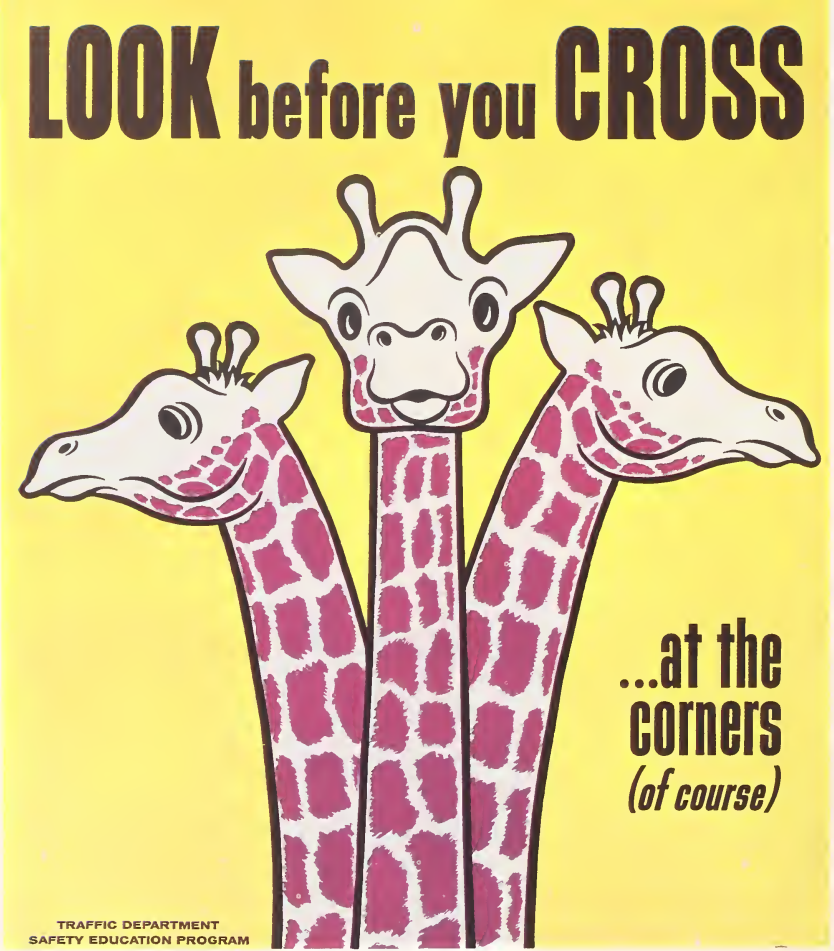
Have the pupils write reports on what their city or town is doing to increase the safety of both pedestrians and drivers. They can write to the traffic department, highway department, and police department to obtain information.

Have pupils also find out what automobile manufacturers are doing to increase safety.

Free instructional aids available to teachers for safety education include:

Bicycle Safety Tests. This booklet presents 15 readily usable and important performance and skill tests for cyclists. Also included is a 25-question test on important rules for cycling. Intermediate or upper-grade level. 18 pages, illustrated. Available to program directors, educators, and others who supervise group activities from the Bicycle Institute of America, Inc., 122 East 42nd St., New York, N.Y., 10017.

Bike Regulation in the Community. This booklet puts forth a program for the regulation of bicycle traffic, the promotion of safety practices, and the elimination of bicycle thefts in the community, through the adoption of a municipal ordinance to register, license, and control all bicycles. Available to program directors, educators, and others who supervise group activities from the Bicycle Institute of America.



And that's the end of the Police Department's traffic safety demonstration. Promise you too will **always** be careful riding your bicyle and crossing the street.

Remember, safety is up to you!

Using What You Have Learned

1. Make a survey in your school to find the answer to these questions:

   a. In what grade do pupils ride bicycles most often?
   b. Where do the pupils in each grade ride their bicycles?
   c. How often do the pupils in your school have their bicycles inspected?

2. Make a plan for a school bicycle safety program. Where could you have it? Who would take part in it? Which adults could help you? Write to The National Safety Council at 425 N. Michigan Avenue, Chicago, Illinois, 60611, for their booklet on bicycle safety.

3. You could set up an Inspection Station for bicycles in your school. You may want to give a Safety Certificate to boys and girls whose bicycles pass inspection.

BICYCLE SAFETY LEAGUE

Membership Card

This certifies that Bike Owner .....

..... has pledged to observe all the Rules of Safe Riding and to keep his bicycle in good operating condition.

(Signed).....
(Safety Supervisor)

Bike Safety Programs. This booklet tells how to plan successful bike safety programs. Chapters on bike safety education, bike safety tests, bike safety rules, bike safety in schools, bike safety films, and bike safety literature. 45 pages. Available to program directors, educators, and others who supervise group activities from the Bicycle Institute of America.

Bikes and Boys and Girls. Here is a short history of bicycles, with easy rules for safe bicycle riding and suggestions on the care of bikes. A special section is included for the fathers and mothers of boys and girls with bikes; a safety quiz for bike riders is included for the boys and girls. Intermediate or upper-grade level. 15 pages. Limit of 50 copies free, from Kemper Insurance, 4750 Sheridan Rd., Chicago, Illinois, 60640.

Water Safety

TEACHING SUGGESTIONS
(pp. 280–282)

LESSON: When is water safe to drink?

Background: A disease of the Orient which made its way to Europe and America was cholera. It caused some of the greatest epidemics of history, killing as many as half of its victims. In March, 1892, a great epidemic of cholera began in India, spread to Europe by May and reached America in September.

During this epidemic, the towns of Altona and Hamburg in Germany both took their water supplies from the Elbe River. In many places, the boundary between these towns ran down the center of the street. During the height of the disease, people on the Hamburg side of the street were sick by the thousands, while nearly no one was ill on the Altona side of the same street. The disease seemed to be stopped by the invisible boundary between the two cities.

It was later discovered that although sewage from the Elbe River entered the water systems of both towns, Altona had a water filtration system of sand, while Hamburg had none. Health experts learned a great deal from this experience.

You know how important water is in our lives. We could not live without it. But water can also be dangerous if it is not used properly. Unsafe drinking water can make us very sick.

Water Pollution

More water is used now than ever before. There are twice as many people in the United States today as there were in 1900. More water is used today for irrigation and for industry.

Many lakes, streams, and rivers that once supplied water for homes and industry no longer do so. These waters are not safe to use. Factory wastes, garbage, and sewage have **polluted** (puh-LOOT-id) the water.

Waste materials from industry cause most of the water pollution. Yet people need the products of industry. The problem is to control pollution without stopping industry.

Making water safe is very expensive. In many towns sewage treatment plants treat the water to make it harmless before it is drained into a stream or lake. Scientists are looking for less expensive ways to get rid of wastes.

Water on Picnics or on Hikes

You are used to getting safe drinking water easily at home. But when you go on a hike or on a camping trip, you may sometimes forget that you cannot always find pure water away from houses and towns. You may forget that not all water is safe to drink.

In some states, signs tell where there is safe drinking water. Boy Scouts and Girl Scouts have helped in some of those places by collecting water samples. The water is tested by scientists to see if it is safe to drink. Scientists use special ways to find out if the water is safe. If the water is safe, signs are placed near the streams or springs.

Finding Out If Water Is Safe

Some water would not fool you at all. It looks muddy and dirty. Try to collect a sample of muddy water from a river or stream. Let it stand in a glass for a couple of hours. Then look at the bottom of the glass. What can you see? How can you get only the clear water into another glass? How can you find out how much mud is in the muddy water? Can you use what

you know about evaporation to find out?

Some water can fool you; it looks pure and clear. But you cannot tell whether water is safe just by looking at it. Sometimes clear water is not safe at all. If the water is not clean, **germs** can grow in it. Germs cause diseases. That is why impure water must be made pure before it is safe for you to drink.

You cannot tell whether water is safe by tasting it. Water from a mountain spring may taste different from the water in your home. It can taste different, and yet still be safe to drink.

The picture above shows the inside of a water purification plant. The picture below shows the aeration part of the plant. What does each of these sections have to do with making water safe to drink?

Do not waste water. Use only as much as you need. This is the way you can do your part to save water.

Learnings to Be Developed:

Unsafe drinking water can make us very ill.

Water that is unsafe is called polluted water.

Many things can pollute water.

Developing the Lesson: You can introduce the subject of water safety through a class discussion of outdoor, summertime fun. Ask the pupils what their favorite activities are and note them on the chalkboard. Then ask:

- *What is the relationship between such things as swimming, boating, picnics and camping, and science?*

Lead children to understand that a knowledge of science can help them to enjoy safer and more healthful outdoor activities.

To introduce the specifics of this lesson, ask such questions as:

- *If you were hiking in the country and had no water, how would you get a drink?*
- *If you came to a spring marked "Safe Drinking Water" but found the water muddy, would you take a drink from it?*
- *If you came to a clear, sparkling mountain stream, would you take a drink from it?*

Now have the children read the material in the text.

Before doing the experiment on page 282, set up a sample of pond water on a slide under a microscope. Discuss this water, along with the settling of the muddy water described on page 280, and the water in the text experiment. The class should develop three generalizations:

1. You cannot tell whether water is safe by looking at it.

2. You cannot tell whether water is safe by tasting it.

3. Water must be tested scientifically to find out if it is safe to drink.

Background: Following are the answers to *Questions to Think About,* page 282.

1. No. One has a definite salt taste.

2. Yes. The same tap water was used in both glasses. The small amount of salt you added may be distasteful, but is certainly not unhealthy. Excess salt in water can be a health hazard, however, because it tends to draw water out of the human tissues rather than supply it. The water from the ocean, for example, contains too much salt for drinking purposes.

EXPERIMENT

Can Water Taste Strange and Yet Not Be Harmful?

What You Will Need

2 glasses of hot water ¼ teaspoon salt

How You Can Find Out

1. Fill two tall glasses with hot water.
2. Put one-fourth teaspoonful of salt into one glass, and stir it until you can't see the grains of salt.
3. Let both glasses stand until the water is cool.
4. Does the water look the same in both glasses? Taste the water in each glass.

Questions to Think About

1. Does the water from each glass taste the same?
2. Are both glasses of water safe to drink? How do you know?

How Can You Make Water Safe to Drink?

On a camping or hiking trip you may find yourself far from safe water. But you may be near a stream, a spring, or a river. In order to drink this water, you need to know how to make it safe. One easy way is to boil the water for about 20 minutes. This will kill the harmful germs in it.

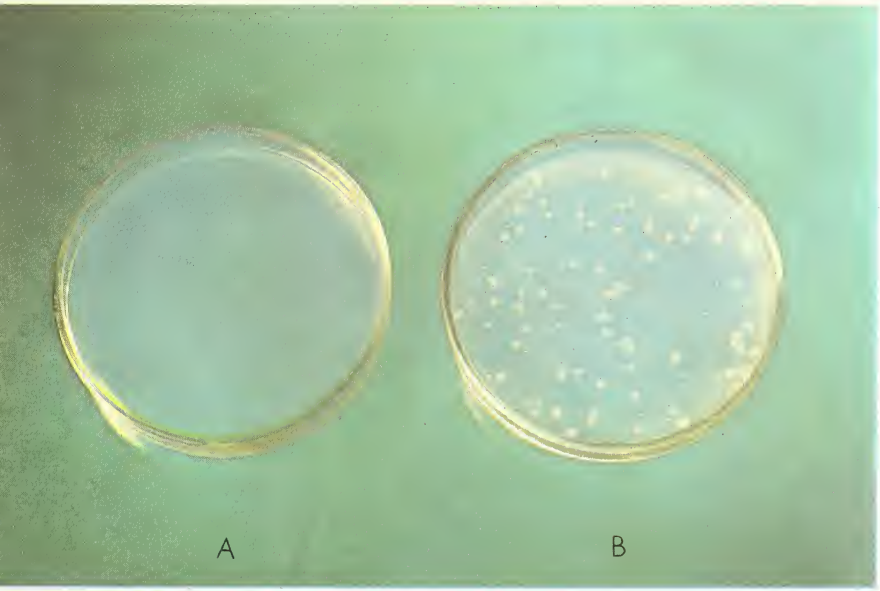
Look at the next page. It shows dishes of a special food where germs can grow. You do not need a microscope

to tell when germs are growing on these dishes. When the dishes are kept warm, the germs grow even faster. Soon there are so many germs that they make spots all over the dish.

Some water from a pond was put into two dishes. But the water had been boiled for 20 minutes before it was put into Dish A. The water had not been boiled before it was put into Dish B. Both dishes were kept warm for two days. Which dish has germs growing on it? What happens, then, when you boil pond water?

Boiling the water will not remove the mud, but there are ways of getting rid of mud in water. One way is to *filter* the water. You can do this by using a special kind of paper called *filter paper*.

What do you notice happening in Dish B, the dish with the unboiled water?



TEACHING SUGGESTIONS
(pp. 283–285)

LESSON: How can you make water fit to drink?

Background: Years ago, much of the water supply for New Orleans came from the Mississippi River. The water of the lower part of the Mississippi contains a great deal of sediment, and many people kept stone filters in their houses. A stone filter is porous rock which allows water to pass through, but holds back mud and most bacteria.

As water stands in reservoirs, most of the heavier particles settle to the bottom. To hasten the removal of impurities, many cities send their water through settling basins or filtration beds. In a filtration plant there are a large number of concrete filtration beds, each of which has layers of sand and gravel. Soil and other particles, as well as bacteria, are caught in these beds.

In some large settling basins, the particles in water are made to settle faster by the use of substances such as alum. This is added to the water to make bacteria, as well as particles, settle quickly. Alum in water produces a thick white substance which attaches itself to foreign particles in suspension, and

carries them to the bottom where they can be removed.

Learnings to Be Developed:

Boiling water kills many harmful germs.

Water can be filtered to remove suspended foreign particles.

Chlorine is one kind of chemical used to kill germs in water.

The purest form of water is distilled water. It is made by first evaporating, and then condensing, the water.

Developing the Lesson: Careful study and discussion of the text should lead children to the conclusion that boiling, filtering, and chlorinating water are only partial measures for purifying it. To achieve really pure water, develop a method for distilling it in class. One way is to boil salted water in a kettle. Place a bowl filled with ice cubes on a ring stand and allow the steam from the kettle to condense by passing it under the bowl. Use a collecting pan to catch the water. Let pupils taste the water in the pan and compare it with the original salted water. It will taste fresh. When salt water evaporates, salt remains in the container.

EXPERIMENT

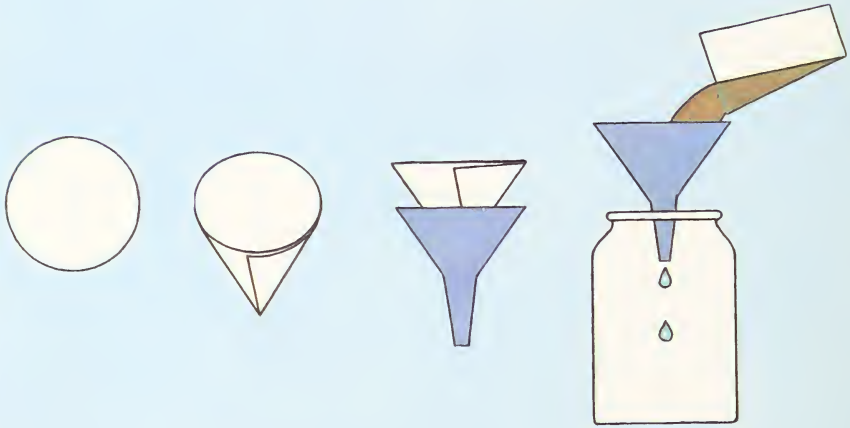
What Happens When Water Is Filtered?

What You Will Need

filter paper	funnel	glass jar
water		garden soil

How You Can Find Out

1. Put a piece of filter paper inside a funnel.
2. Place the funnel in the mouth of a glass jar.
3. Pour some water, with garden soil mixed in it, into the funnel.
4. Watch what happens to the soil. Look at the water in the jar. Does it look clean?



Questions to Think About

1. Do you think the water in the jar is safe to drink?
2. Do you think the water in the jar would be safe to drink if you boiled it for twenty minutes?

If you first filter and then boil the water from a stream or river, it will be safe to drink.

There is another way to kill the germs in water. You may have noticed that the water in swimming pools sometimes has a strong smell and makes your eyes burn. The **chlorine** (KLOR-een) in the water does this. Chlorine is put into the water to kill germs. Too much chlorine is not good for people. A very small amount of it is put into drinking water. Only enough chlorine is used to kill the germs. Many cities put chlorine in their drinking water to make the water safe to drink.

How Can We Get Pure Water?

You know that boiling kills germs. The germs remain in the water, but since they are dead, they are harmless. Water that has been boiled may be fit to drink, but it is *not* pure water.

Pure water has *no plants or animals of any kind in it.* It does not even have any minerals in it. To get pure water we have to make the water **distilled** (dih-STILD).

The first step in distilling water is to boil it. The dirt and minerals stay in the container, as they did when you boiled the water with soil dissolved in it. But what happens to the water itself? It seems to disappear. It changes from liquid water to water gas, or vapor. This is called **vaporization** (vay-per-ih-ZAY-shun). As the water changes to steam, it becomes pure.

The second step is to condense the water vapor back to liquid water. When the steam has been cooled and collected, it is pure water. It does not contain mud or minerals. Does it contain germs? How do you know?

You can distill water in your classroom. To see how you can get pure water by distilling, add about a teaspoon of salt and some food coloring.

Plan how you will cool the steam and collect the distilled water. What will happen to the salt? Will the distilled water taste salty? Will it be colored?

Swimming and Playing in the Water

Playing in the water can be great fun, if . . . .

Can you complete the sentence? Probably the first ending should be *if you can swim.* Another should be, *if the water is clean.* A third should be, *if there is an older person with you.*

Background: Following are the answers to *Questions to Think About,* page 284.

1. No. It is safer than when it was muddy. However, the invisible germs (virus, bacterial and protozoan) were not eliminated by this method. Soil contains many organisms harmful to humans.

2. Under most conditions, this would be safe. (However, if the pollutants were soluble toxins, boiling would have no effect.)

ADDITIONAL ACTIVITIES:

Let a committee investigate and report to the class on the most common types of water pollutants. These include industrial wastes, sewage, animal droppings, stagnant pools and ponds, swamps, manmade chemicals used in insect control, etc.

Find out why many large cities are currently plagued with water shortages, and what they are doing to alleviate the problem.

Investigate the source of your local water supply and report to the class on its treatment before it comes out of the home faucet.

Investigate the use of atomic energy in the conversion of ocean water to potable water.

(pp. 286–288)

LESSON: What are the water safety rules in swimming?

Learnings to Be Developed: Refer to the five "Water Safety Rules" shown on the page.

Developing the Lesson: Discuss the safety rules in the text. Ask for an explanation of each rule to be sure pupils understand them completely. Ask for suggestions for additional rules. These rules might include: Don't annoy fellow swimmers. Don't indulge in horseplay. Stay off the high board unless you are an experienced diver. Pay attention to the lifeguard.

Ask the children if any of them have home swimming pools. Have them give a summary of the treatment necessary for keeping the pool clean and pure.

ADDITIONAL ACTIVITIES:

Demonstrate the mouth-to-mouth method of artificial respiration. The American Red Cross advocates this method for infants and small children. The procedure is as follows:

1. Clear the mouth of any foreign matter with the middle finger of one hand. With the same finger press the tongue forward.

Be Sure You Can Swim

One of the first things that a beginning swimmer should learn is how to float. You can float facing down or facing up. If you lie on your back and keep your nose and mouth above the water, you can float for some time. Since the water holds you up, all you have to do is to learn how to move your arms and legs and to breathe without taking water into your lungs.

If you do not know how to swim, a good swimming instructor or an adult who is a good swimmer can teach you in a few lessons. Then by practicing you can become a good swimmer. A safe swimmer is one who never takes chances.

In the picture below are five rules for safety in the water. Why are these good rules? Be sure to remember them and to obey them.

WATER SAFETY RULES
1. Never swim alone.
2. Never jump or dive when you do not know how deep the water is.
Never show off in the water.
Wait at least an hour after meals before going into the water.
5. Stop swimming before you get too tired.

Be Sure There Is an Adult with You

A careful swimmer never swims alone. No matter how good a swimmer you are, there is always a possibility that something may happen to you. Sometimes very good swimmers get cramps in their arms or legs and are not able to move them. Sometimes they get cramps in their stomachs and cannot straighten out. When this happens they may not be able to swim or float. They must have help. If they are alone they may drown.

If you are a beginner, be sure you are safe while you learn. Never try to learn by yourself. Never go swimming when the only person with you cannot swim either.

Try hard to become a good swimmer. Nearly always the safest swimmers are the good swimmers.

Always make sure there is a grownup with you when you go swimming. Why is this important?

Be Sure the Water Is Clean

There are many ponds and lakes where the water is not fit for swimming. The water is dirty. It has germs in it that will cause swimmers to become sick. Just as the health department in your city or county checks drinking water for germs, it also checks public swimming places. If you swim in a public place you can usually be sure that the water is clean. People who have their own backyard swimming pools must be very careful to keep the water clean and to kill all the harmful germs that get into it. You can get skin diseases, and some other diseases, very easily if you swim in water that is not properly cleaned.

2. Now place the child in a face-down, head-down position and pat him firmly on the back with the free hand. This should help dislodge any foreign object in the air passage.

3. Place the child on his back and use the middle fingers of both hands to lift the lower jaw from beneath and behind so that it "juts out."

4. Hold the jaw in the position described in Step 3, using one hand only.

5. Place your mouth over the child's mouth and nose, making a relatively leakproof seal, and breathe into the child with a smooth steady action until you observe the chest rise. As you start this action, move the free hand to the child's abdomen, between the navel and the ribs, and apply continuous moderate pressure to prevent the stomach from becoming filled with air.

6. When the lungs have been inflated, remove your lips from the child's mouth and nose and allow the lungs to empty. Repeat this cycle keeping one hand beneath the jaw and the other hand pressing on the stomach at all times.

Continue at a rate of about 20 cycles per minute. After every 20 cycles the operator should rest long enough to take one deep breath. If at any time you feel resistance to your breathing into the child and the chest does not rise, repeat Step 2, then quickly resume mouth-to-mouth breathing.

Background: Here is additional information and answers to *Using What You Have Learned,* page 288.

1. Look up "Water treatment" in the Yellow Pages of the telephone directory. Investigate the possibility of one of the listed companies sending a representative to speak to your class.

2. Salt water is more dense than fresh water and weighs more per cubic foot. Because of this it will buoy up anything immersed in it, better than fresh water will. Floating in the ocean is easier than floating in a fresh water lake, provided both are calm.

Using What You Have Learned

1. Plan a visit to a place where the water is treated so that it is safe to drink. Find out how it is treated.

   Have your class plan a list of questions that they would like to have answered. Perhaps someone in your class can interview one of the scientists. Your class might try to write their own report called "Meet the Scientist."

2. Show whether it is easier to float in salt water than in fresh water. Fill a pot with water from the faucet. This stands for a lake. Put a fresh egg into the "lake." What happens to the egg?

   Now stir in a teaspoon of salt to the water. You now have an "ocean." What happens to the egg?

   What does this tell you about floating in lakes and in oceans?

Fire Safety

Fire under control is one of our best friends; out of control it is one of our worst enemies. Each year, fires destroy more than one billion dollars' worth of property. This is about the amount of money it would take to build homes for 250,000 people. Would this be enough to build homes for all the people living in your city or county?

During one year, more than 6,000 people were killed by fires in their homes. In fact, a common cause of injury to children of your age group is fire or objects that have been heated by fires. If you have made the survey on page 265, you can check it to see how many of your classmates may have been injured by fire.

What Does Fire Need to Burn?

We know that fire causes many accidents. If we are going to do a better job of controlling fire, we must find out all we can about it.

A fire needs certain things from the air to burn. You can show this by doing the following experiment. Be sure you do this experiment only when a teacher or other adult is watching.

EXPERIMENT

Does Fire Need Oxygen from the Air to Burn?

What You Will Need

4 candles
4 pieces of metal
matches
4 jars (small jar, pint jar, quart jar, and very large jar)

How You Can Find Out

1. Melt the end of a candle so that it will stand on a piece of metal.
2. Light the candle and lower the smallest jar over it. What happens? Why?
3. Stand three other candles on pieces of metal.
4. Lower the other three jars over the candles. You will need someone to help you do this. Be sure that you lower all three jars at the same time.
5. Time how long each candle burns.

Questions to Think About

1. Which candle went out first? Why?
2. Which candle went out last? Why?
3. How long did each candle burn?

TEACHING SUGGESTIONS
(pp. 289–291)

LESSON: What is a fire and what are its needs?

Background: Fire strikes an average of 1,500 homes, 10 schools, 9 churches, and 3 hospitals in the United States every day. Most deaths from fires occur in homes, and the usual reason is an inability to find an escape route. This should certainly point up the need for fire drills in family dwellings, as well as in public places. Most families never have such drills, nor do they even have plans for evacuation, although both procedures are constantly being recommended by fire casualty companies. The teacher's emphasis and concern in this area might contribute to having drills performed, or at least discussed, in the pupil's homes.

Learnings to Be Developed:

A fire needs air, fuel, and heat in order to exist.

Oxygen from the air keeps a fire burning.

Developing the Lesson: Let pupils imagine what the world would be like without fire. List the things we would be unable to do, and the things which we could not make. Pupils may learn more

about the importance of fire by making a survey of places in the community where fire is used. They may also learn what safety precautions are taken in these places, to prevent fires.

Now ask pupils about their own experiences with fire. Let them describe the procedure of building a campfire, or a fire in an indoor fireplace. They will indicate that dry leaves or paper are put on the bottom, then small dry twigs are added, and finally, large pieces of wood are placed on top.

Let children discuss the next step in building a fire. They will say that first the paper is lit, then the twigs, and lastly the large pieces of wood. Bring out the point that a source of heat has been used. This source is probably a match for the campfire. Discuss other sources of heat, such as are described on page 291 of the text.

The experiments in this lesson clearly illustrate the third need of a fire—air. In doing these experiments, it is essential that the utmost caution be exercised in the handling of matches, fuel, and fire. It would be best for the teacher to demonstrate safety precautions for dealing with fire, before beginning the experiments.

You have seen that a lighted candle goes out when it is shut up in a jar. It will go out as soon as it uses up most of the oxygen in the jar. It will burn longer in a quart jar than in a pint jar because there is more oxygen.

What do you think would happen if you lowered a lamp chimney over a lighted candle?

Is it better to have air come in at the bottom or the top of the chimney? You can find out.

EXPERIMENT

Is the Flame Brighter If Air Comes In at the Bottom or at the Top of the Chimney?

What You Will Need

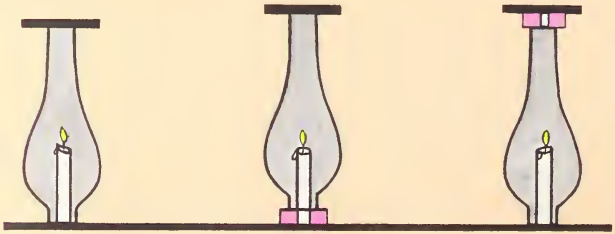
3 candles	3 lamp chimneys
piece of metal	4 pieces of wood

How You Can Find Out

1. Stand three candles on a piece of metal.
2. Cover one lighted candle with a lamp chimney.
3. Put the second chimney over the second candle, resting the chimney on two pieces of wood so that air can come in at the bottom.
4. Cover the third lighted candle with the third lamp chimney.
5. Put two pieces of wood on the top of the third lamp chimney.
6. Cover the top of each chimney with a piece of metal.

Questions to Think About

1. Which candle burns the brightest?
2. How does the air get into the chimney?



The fact that fire needs air should help you think of ways to make a fire burn more brightly. Why do you sometimes fan a campfire to make it burn better? Why is it dangerous to build a fire outdoors on a windy day?

You have found that a candle flame goes out when there is not enough oxygen. This fact should help you think of some ways to put out a fire.

Can you explain why a fire can be put out if it is covered with sand? Can you give a good reason for smothering a small fire with a heavy blanket or with a rug?

Next time you are in a restaurant, movie theater, or department store, notice how many different ways have been provided to put out fires. How does each of these ways work?

How Is Fire Started?

Rubbing things together can cause heat. You can prove this by rubbing your hands together or by rubbing your fist across your desk. You can heat an eraser by rubbing it hard on a piece of paper for a minute or so.

If you rub some things hard enough and long enough, you can cause enough heat to start a fire.

Long ago, the Indians started fires with a bow and drill. When the Indian pulled the bow back and forth rapidly, the end of the drill and the piece of wood became very hot. The Indian had some broken-up dried leaves, or something else that burned easily. He placed them around the end of the drill, and they would soon catch fire.

When an astronaut's capsule hits the atmosphere upon returning to the earth, the metal of the capsule gets very hot. It gets hot because the air molecules rub against its surface rapidly. It gets so hot that it would burn up if it were not slowed down. Do you know how scientists slow it down? How can you find out?

There is another way that fires start. A pile of oily rags or papers will produce a small amount of heat. If this heat cannot escape easily, the pile may become very hot. The rags may become so hot that they will burst into flame. This could happen in your home if a pile of oily rags or papers were stored in your cellar or attic. Many fires have started this way. They have burned homes and other buildings. These fires could have been prevented if someone had been more careful.

Background: Following are the answers to *Questions to Think About,* page 289.

1. The smallest jar contained the least amount of air, and that flame died out first.

2. The candle in the largest jar was the last to be extinguished. This jar contained the greatest amount of air (oxygen).

3. Until the supply of available oxygen was depleted. Time will vary with the size of the jar and the type of flame. Candles with large wicks will tend to consume the oxygen faster and burn brighter. For this reason, use candles of uniform size and wicks. The only experimental factor should be the amount of oxygen.

Following are the answers to *Questions to Think About,* page 290.

1. The second candle should burn brightest. Here, the flow of air is upward past the burning wick. Outside air is cooler than inside air. Where there is an opening at the bottom, the cool air enters in a constant flow to replace the rising hot gases.

2. In the first chimney, no air can enter. In the middle one, air enters at the base. In the third chimney air enters at the top, but is impeded by the flow of the hot gases upward.

TEACHING SUGGESTIONS
(pp. 292–293)

LESSON: How do we extinguish fires?

Background: Since the requirements for a fire are oxygen, fuel, and heat, eliminating one of these ingredients should extinguish a fire. Indeed, smothering, cooling, and removal of the fuel are the three most usual methods of putting out a fire. In unusual circumstances, such as a fire in an oil field, a large explosion may be used to send a compression wave, which blows out the fire in a manner similar to blowing out a match with your breath.

Learnings to Be Developed: Fires are put out by smothering them, cooling them, or by removing the burning fuels.

Developing the Lesson: A careful study of page 291 will make it obvious that when things become hot enough they will burn, provided a good supply of air (oxygen) is present. If there are any Scouts in the class, they may be able to demonstrate how to start a fire by using friction. Such an activity should be carried out on the school playground or other outside grounds.

Have pupils recall the three requirements for fire: air, fuel, and

How to Put Out Fires Safely

You have learned that it takes three things to make a fire. First, there must be something to burn. Second, there must be oxygen. Third, the material must be heated. If you want to put a fire out, it is important to know what fires need to burn.

When you want a fire to die out by itself, you sometimes let all the material burn up. When this happens, there is nothing left to burn and the fire goes out. This is what happens to a fire in a fireplace if you do not keep adding wood or coal to it.

Fires need oxygen from the air in order to burn. Fires go out if they do not get enough air. You saw this happen when you covered a candle flame with a jar cover. This also happens when you cover a fire with sand or soil. You have probably seen a fire put out with water.

Water helps to put out fires in two ways. The water and steam cut off the air which the fire needs. The water also cools the burning material. This keeps the material from burning easily.

We know that we must be careful to put out our campfires. All these ways can be used.

How Fire Extinguishers Work

You have seen fire extinguishers in your school and in other places. They should always be handy and in good working order. There are several kinds of fire extinguishers.

One kind of fire extinguisher is filled with water and baking soda. Inside it there is a little bottle near the top. The bottle is filled with **acid**, which is a liquid. This acid is something like vinegar, but stronger. It is so strong that it would burn your skin if you touched it.

When the fire extinguisher is turned upside down, the acid in the bottle mixes with the baking soda and water. This makes a gas called carbon dioxide. It collects at the top of the tank and forces the water out through the hose. The water puts the fire out.

This kind of fire extinguisher can be used to put out small fires. If a house is on fire, a small fire extinguisher is not enough. The fire department is needed.

Can a gas be used to put out fires? Try the experiment on the next page to find out. *Be sure to have your teacher or another adult help you do this experiment.*

Can Carbon Dioxide Put Out a Fire?

What You Will Need

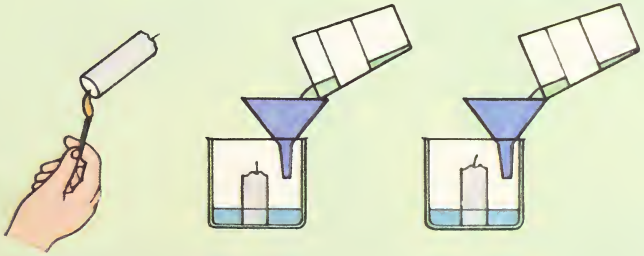
2 glass jars	half a cup of warm water	some vinegar
2 short candles	tablespoonful of baking soda	funnel

How You Can Find Out

1. Melt the bottom ends of the candles.
2. Stand one candle in each jar.
3. Pour a half cup of vinegar into one jar, using a funnel. Be careful not to wet the candle wick.
4. Light the candle. Does anything happen to the candle flame?
5. Pour the warm water and baking soda into the second jar. Do not wet the candle wick.
6. Light the second candle.
7. Pour a little vinegar into the second jar. Vinegar is an acid. When the vinegar mixes with the baking soda and water, bubbles of carbon dioxide form. What happens to the candle flame?

Questions to Think About

1. Why did the candle burn in the first jar?
2. Why do some fire extinguishers have baking soda, water, and acid in them?
3. What other kinds of fire extinguishers are there? What do they contain? How do they put out fires?
4. Why should water never be used to put out a fire started by electricity?
5. What kind of fire extinguisher should be used for an electrical fire? How does this extinguisher work?



heat. Demonstrate how the removal of any one of these requirements can extinguish a fire.

The simplest demonstration of putting out a fire by removing the air supply is to cover a lighted candle with a glass.

To demonstrate the removal of fuel, place a few crumpled pieces of paper in a metal dish. Set fire to one piece and remove the other pieces of paper, using a pair of tongs.

To illustrate cooling a fire, pour water over a piece of burning paper in a metal dish.

Background: Following are the answers to *Questions to Think About,* page 293.

1. Nothing interfered with the three requirements for a fire.

2. The baking soda and vinegar (or other acid) react to produce carbon dioxide. The carbon dioxide gas builds up pressures strong enough to propel a stream of water to the center of the fire.

3. See pages 294–295 *Background.*

4. Water conducts electricity, and the danger of electrocution is as hazardous as is burning. Water may also cause a short circuit which could start a fire at another location due to overheated wires.

5. See page 292 for description.

(pp. 294–295)

Background: Discuss the fire safety rules shown on these two pages.

This might be an appropriate place to also discuss the various types of fire extinguishers, below:

1. *Water Pails.* The use of buckets and pails is limited to small fires.

2. *Soda and Acid Extinguishers.* A description of this type is on page 292 of the text. In this type of extinguisher two fluids are present: sulfuric acid and sodium bicarbonate solution. The main agent for extinguishing fire is water.

3. *Calcium Chloride Extinguishers.* The liquid discharge is a nonfreezing mixture of calcium chloride and water. These extinguishers are made for use where extreme temperatures would place the ordinary soda-acid extinguisher out of commission.

4. *Carbon Tetrachloride Extinguishers.* Carbon tetrachloride is noncombustible, and in the presence of heat changes to a heavy poisonous gas which smothers the fire. Since it does not conduct electricity, it is used on electrical fires.

FIRE SAFETY RULES

DO

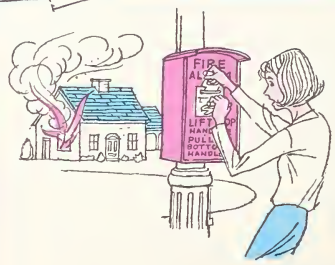
1. Use sand, ashes, or water to put out fires.

2. Know how to smother fires with a blanket or rug.

3. Put hot ashes in metal containers.

4. Strike matches away from yourself.

5. Keep oily mops and rags in a tightly covered container.



6. Know how to turn in a fire alarm.

DON'T
MATCHES
1. Don't leave matches where small children can get them.
2. Don't light bonfires unless a grown-up is with you.
3. Don't start a fire on a windy day.
KEROSENE
4. Don't use kerosene or gasoline to start a fire.
5. Don't use liquid fuels to make a fire burn better.
6. Don't use matches or candles to light up dark places.

5. *Sand Fire Pails.* These are effective on small fires of flammable liquids and greases, but are not too effective in open vessels.

6. *Carbon Dioxide Extinguishers.* The portable size consists of a small steel cylinder filled with carbon dioxide gas under very high pressure. This gas is released by opening a valve, and is discharged through a short length of hose fitted with a funnel-shaped nozzle. The release of this gas into the air causes the formation of carbon dioxide "snow," a white substance of intense coldness. Because this snow has tremendous cooling power, and the gas has a high extinguishing effect, this type of extinguisher is very popular.

7. *Foam Extinguishers.* Trucks produce foam, to spread over runways, for emergency aircraft landing. Upon landing, the engines and gasoline tanks are usually also sprayed with this thick candy-like foam which smothers any fire that might start. Used in open tanks of burning gasoline, the foam floats on top and smothers the flame.

8. *Dry Chemical Extinguishers.* The simplest of these contains baking soda, which in the presence of heat decomposes and forms carbon dioxide gas, which spreads over the burning area. Other chemicals are also used.

TEACHING SUGGESTIONS
(pp. 296–305)

● **LESSON:** What can you learn about fire safety from a fire department demonstration?

Learnings to Be Developed: See the twelve "Fire Safety Rules" listed on pages 294–295.

Developing the Lesson: The most effective way to teach this lesson is with live demonstrations given by the fire department of your community. Do not think you are imposing on the department when you request assistance in teaching fire safety. Most fire departments maintain special lecturers and demonstrators for this purpose, and all departments welcome a chance to speak on this very important topic.

If a speaker from your local fire department does come to class, or if you can arrange for the pupils to visit the fire station, advance preparation is essential. Spend time having the children make up a list of good questions to ask the firemen, in order to get the most out of their visit. These might include:

- *What kinds of equipment do firemen use to put out fires?*
- *When do they use fire extinguishers?*

Fire Prevention

Fire is one of man's greatest helpers. But it can be a terrible enemy if it is allowed to get out of control. The best way to keep fires from causing damage is to keep them from starting where they are not wanted. This is what we mean by **fire prevention.**

Some children in your school may not know as much as you know about preventing fires. You may want to plan a fire prevention program for them. You can tell them some of the things you have learned about fire. You can tell them the rules that children must obey to prevent fires.

ABOUT "FIRE SAFETY"

Just as bicycle safety and traffic safety are up to you, so is fire prevention. Thousands of lives and millions of dollars' worth of property could be saved each year if people observed some very simple rules. You will now learn what these rules are from members of the New York City Fire Department.

- *When do they use hoses?*
- *What kinds of extinguishers are used in fighting fires?*
- *What kind of clothing does the fireman wear to protect himself?*
- *What kind of training does the fireman have?*
- *What kinds of fires are there?*
- *How is each of these fires caused?*
- *How might each of these fires be prevented?*
- *What precautions against fire can be taken in our schools, homes, and public buildings?*
- *What kinds of devices should be in the home to fight fires?*
- *What should be done if a fire is discovered in the home? In school?*
- *What are the most common types of fires in this neighborhood?*
- *How may these fires be prevented?*
- *How are tall buildings protected from fire on the upper stories?*
- *Are buildings inspected by the fire department to make certain they are safe?*

What happens if a building is found to be unsafe?

Are there laws about fire safety for homes, schools, department stores, movie theaters, etc.? What are these laws? How are they enforced?

Why do buildings bulge outward from the top during severe fires?

Why do firemen cut holes in the roof of a building when a fire is in progress?

How do firemen get water to very tall buildings?

What are the most difficult types of fires to fight in this community?

What are some of the tools used by firemen, and how are they used?

How should a fire alarm be turned in?

Are many false alarms turned in each year?

What are the dangers of turning in a false alarm?

ADDITIONAL ACTIVITIES:

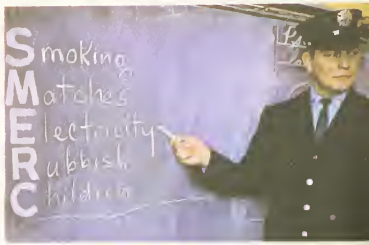
Discuss the importance of fire drills and how they can be improved.

Have pupils report to the class on different ways of fighting fires.

A visit to a classroom by firemen is an important part of a Fire Department's fire prevention program.

To start his demonstration, the fireman draws a triangle on the board. He writes the letters **H, O,** and **F,** one for each side of the triangle, and asks if anyone can tell him what the letters stand for. The letters stand for **H**eat, **O**xygen, and **F**uel. These are the three ingredients that make a fire. If you remove any one of these three ingredients, the fire will go out.

What causes a fire? Here you see five important causes listed. You can remember them by knowing what **SMERC** stands for. **S** is for *smoking* in bed, **M** is for playing with *matches,* **E** is for *electrical* fires caused by overloading of circuits, **R** is for *rubbish* such as oily or greasy rags, which ignite if kept in confined areas, and **C** is for *children* who are left alone and who may get into trouble.



On the next page, you see the three classes of fires—**A, B,** and **C.** Before you put out a fire, you must know what kind of fire it is. Then you must know which fire extinguisher to use on the fire.

Examine the school's fire extinguishers. Point out exits to use in case of fire. Show fire alarm bells and fire alarm boxes in the school.

CLASS **A** FIRES
Paper, wood, cloth, rubbish.
Water puts out the fire by its cooling effect.

CLASS **B** FIRES
Burning liquids (gasolines, oils, paints, cooking fats).
Foam smothers the fire. Foam floats on top of the liquid, acting as a blanket. It keeps out oxygen. Carbon dioxide may also be used on this type of fire.

CLASS **C** FIRES
Live electrical equipment (motors, switches, appliances).
Carbon dioxide is used, because it does not conduct electricity.

Have pupils check their homes for fire safety, by asking their family to help fill out the Fire Safety Checklist, available from the National Board of Fire Underwriters.

Check the school for fire safety. The Safety Inspection Blank for Schools may be used. Examine the school heating system. Find out how the fire extinguishers work. Your school custodian might help the pupils in this check.

Appoint a committee to report on matches. Let them look into the history of the match, and report on how matches are manufactured. Have them demonstrate the differences between safety matches and friction matches, and demonstrate the proper way to strike a match. Discuss the reasons for closing the cover of a book of matches before striking one and for other safety rules.

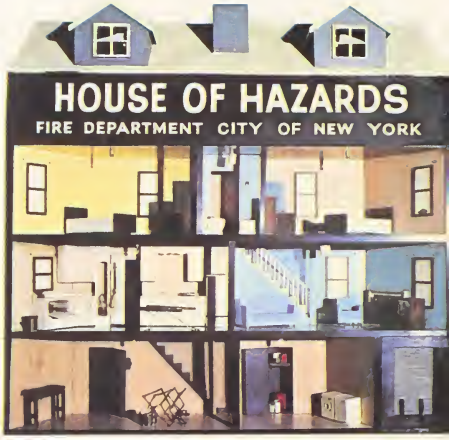
Let pupils make exhibits of common materials used as fuels in your community. Have them look into the composition of these fuels and discuss their comparative advantages and disadvantages. If your locality uses coal gas, investigate what it is, where it comes from, and how it is obtained. Do the same for natural gas and bottled gas.

Show why some foods are called "fuel" foods. Heat small amounts of butter or olive oil until they burn. Try burning bread and nuts. Burn sugar, by first dipping it into ashes. Discuss what this means in relation to providing energy for the body.

You may want to reproduce a miniature explosion of the kind that can occur in flour mills and grain elevators. This should be done only by the teacher. Light a candle. Set it in a candlestick. Fill a drinking straw with ¼ teaspoon of cornstarch. Aiming away from the children, blow the cornstarch at the flame. It will ignite in a brief explosion. (Because the particles are so small, and the flame so brief, the experiment is quite safe.) Coal dust in mines may explode in the same way.

You might purchase a convection box to demonstrate the flow of gases when heated. This apparatus can be obtained from the Stansi Company in Chicago.

The children have already learned that there are three conditions necessary to have fire—heat, fuel, and oxygen. If any one of these conditions is missing, the fire will go out. Water is often used to put out paper, wood, or cloth fires. Water itself does not burn and is



The House of Hazards shows all the places where fires may occur in a house. Can you name these places? Can you tell what may cause fires in each of these places?

Notice that every room is a fire hazard.

We use a great deal of electricity in our homes. Look at all the outlets in your home. There are wires carrying electricity to each of the outlets. If not used properly, electricity can be a destructive force. In these pictures, a fireman explains what happens when you overload an electrical circuit by using too many appliances.

Every electrical circuit in your house or apartment is fused. Without the fuse, electrical current will not flow through the wires. Whenever a fuse is replaced, the electricity should **always** be shut off first, by pulling the lever to the *off* position.

Here you see the fireman plugging in three appliances.

Next, he also plugs in the toaster. Look at the lamp bulb and the fan. What do you see happening? Do the lights in your house dim when you use a toaster or a fan? Does your television picture shrink when the vacuum cleaner is in use? You may be overloading the circuit. Does your outlet look as though an octopus is plugged into it? You may be plugging too many appliances into one outlet.

The lamp dims; the fan slows down.

Some people replace the fuses they have been using with fuses having a higher rating. Now let's see what happens to the wires in the walls when this is done.

Replace a fuse only after pulling the lever on the fuse box to OFF.

capable of absorbing much heat. This cooling effect brings the burning material below its kindling temperature, and the fire goes out. Water also serves to wet the fuel so that it becomes less combustible. To illustrate the effectiveness of water as an extinguishing agent try the following:

Dip most of a wooden match in water. Try lighting the moist head of the match in a candle flame. Compare how long it takes to ignite with the time required for a dry match to ignite.

You might also like to try putting out a candle flame with a perfume atomizer filled with water.

If you keep air away from a fire, the fire will go out. One way to do this is by replacing the air with a heavy, noninflammable gas such as carbon dioxide. Try putting dry ice into a metal container. Use gloves to handle the dry ice. Let the dry ice stand for a while to fill the container with carbon dioxide gas. Next wrap a wire around a lighted candle and lower it into the container. The flame will go out. Another way to keep air away from a fire is to smother the fire with sand. If clothing should catch fire, smother it with a rug, blanket, or coat. Do not run; if you do, the breeze will fan the flames.

Discuss how the sun's rays, when focused properly, can cause a fire. Try this demonstration. First place a match in a metal container. Next, use a magnifying glass to focus the sun's rays on the head of the match. The head will burst into flame. Focus the sunlight on a pupil's hand for a few seconds and have him note the heat produced.

Try placing a round goldfish bowl in the sunlight. Find where the sun's rays come together at a point. Place a thermometer near or inside the bowl so that the sun's rays focus on the bulb of the thermometer. Note the rise in temperature. Discuss how soda bottles can cause forest fires in this manner.

Using the pictures on these pages, discuss how poor electrical wiring can be a hazard. Electricity, as the children have learned, produces heat. Sometimes, as shown in the pictures, wires become overloaded; or insulation around a wire may be worn away until the wires are exposed and touch. A short circuit may result. The heat of the wires may set the walls on fire.

Show that a lampshade may catch fire when the electric light bulb of the lamp is too near the shade. Wrap a piece of paper around a

The larger fuse allows more electricity to flow through the wires. But the wires are not able to take such a load, and they get very hot.

This is what happens when a piece of paper is touched to the wire. First smoke, then fire appear. In your walls, the hot wire burns through its insulation. The walls catch fire.

If you use the proper fuse, this will not happen. Instead, the fuse will blow (see fuse on right), shutting off the current. The wires will not become hot, and you have been warned that you have overloaded your circuit. Some homes have circuit breakers that act as fuses Find out how a circuit breaker works.

YOUR NEW YORK CITY FIRE DEPARTMENT
0000
FIRE CAUSES
Fuses too large or tampered with
2 Overloaded wiring
3 Worn out wiring and equipment
4 Defective appliances
5 Do-it-yourself electrical work
6 Electric cords 'Octopus' outlets
SERVICE SWITCH
ON
OFF
FUSE BOX
INADEQUATE WIRING CAN CAUSE FIRES!
FIRE PREVENTION
1 Use proper size fuses
2 Don't overload wiring systems
3 Modernize old wiring systems
4 Have defective appliances repaired
5 Don't do your own electrical work. It's illegal
6 Have frayed or worn cords replaced
7 Eliminate 'octopus' outlets
THE BEST WAY TO ELIMINATE POTENTIAL FIRE HAZARDS IS TO HAVE A LICENSED ELECTRICAL CONTRACTOR MAKE SURE YOUR WIRING SYSTEM IS ADEQUATE
ROBERT F. WAGNER
MAYOR
EDWARD THOMPSON
FIRE COMMISSIONER
CITY OF NEW YORK

100-watt bulb in a socket. Turn the current on and watch what happens. In a few minutes the paper will be scorched.

You can show how fireproofing retards fires. Use 2 ounces of ammonium sulfate, ½ ounce of borax, and ½ ounce of boric acid. Then, place all three chemicals in enough warm water so that they are completely dissolved. Dip a piece of paper in the solution and let it dry. Apply a candle first to ordinary paper, then to the fireproofed paper. Do this over a sink.

The following books will be of interest to teachers:

Experiments with Fire, by Marian Baer (Holt, 1947).

Fuels and Fire, by G. Bruce (National Science Teachers Association, 1951).

Your pupils will enjoy reading:

Fire in Your Life, by Irving Adler (Day, 1955).

Fire, by Bertha Morris Parker (Harper, 1941).

Fire, Friend and Foe, by Bertha Morris Parker (Harper, 1948).

The following materials might be ordered for your classroom library:

Fire Safeguards for the Farm, FB.1643. This bulletin tells how to lessen or avoid fire hazards on farms and thus add to the safety of both property and persons. It points out how an individual farmer can further reduce the probability of serious fire losses by using simple home equipment with which a small fire can be quickly put out. 32 pages. Limit of 5 copies. Available to teachers and librarians only. U.S. Department of Agriculture, Agricultural Research Service, Washington, D.C., 20025.

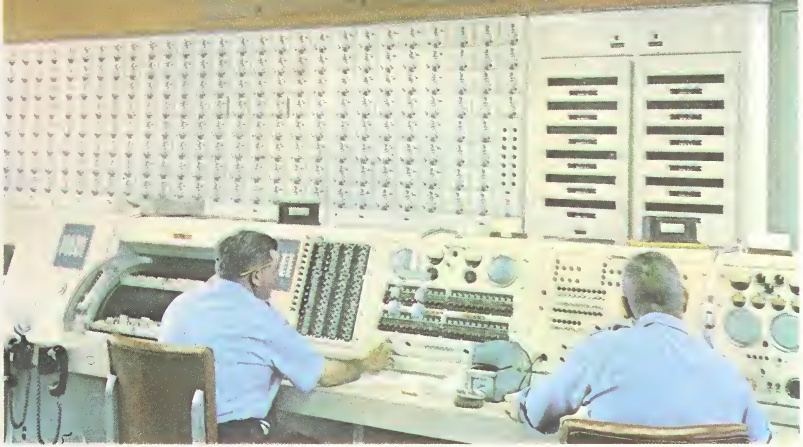
Fundamentals of Fire Extinguishment. This leaflet presents a discussion of what fire is, the three main classes of fire, the characteristics of flammable liquids, and the proper methods of fire extinguishment. 4 pages, illustrated. Single copies. Ansul Chemical Company, Marinette, Wisconsin, 54143.

Safety Action Program. This booklet is divided into three parts: Highway Safety, Farm and Home Safety, and Fire Prevention. The booklet is set up in the form of programs for special meetings. It includes songs, film listings, poems, and talks. 16 pages, illustrated. Single copies. The National Grange, 744 Jackson Place, N.W., Washington, D.C., 20006.

What should you do when, through carelessness or other means, a fire does occur? Immediately send a fire alarm, either by telephone or by fire alarm box.

The way to turn in a fire alarm is shown on the left. Lift up the guard; then pull down the handle inside. Wait for the engines to come and direct them to the fire. If you telephone, tell the operator the address of the fire and give your name and telephone number. Wait for the engines to arrive and direct them to the fire.

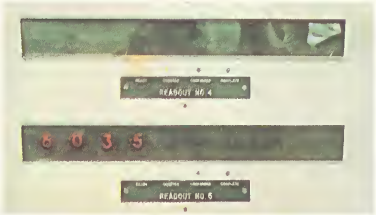
What happens when you send in the alarm? If you look at a fire alarm box, you will see that it has a number. The number on the box in the picture is 6035. When you pull the handle, the number 6035 is tapped out by means of a telegraphic system: first 6 taps, then 10 taps for 0, then 3 taps, then 5 taps.



This code is received at a Fire Department Communications Center. At the communications center, the men on duty listen as the alarm comes in.

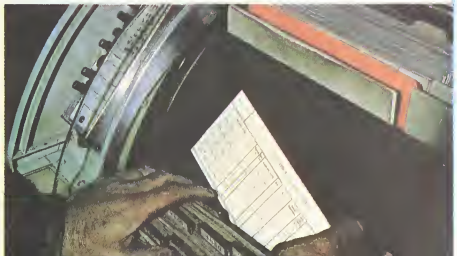
Here you see the alarm board, where all the fire alarm boxes are represented.

Meanwhile, the code number of the alarm box is also flashed on another board, so that there can be no mistake.



As soon as they identify it as 6035, they go to a card file and find the card for Box 6035.

This card tells them where the fire alarm box is located and which fire companies are in the box's zone.



What You Should Know About Fire Extinguishers. Describes the different kinds of fires and the different extinguishers used on them. Available in classroom quantities from Pyrene Manufacturing Co., 560 Belmont Ave., Newark, N.J., 07108.

Your Fire-Safe Home. This pamphlet presents information on what can be done in the home to prevent fires. Helpful information regarding action to be taken in case a fire does occur is also presented. Single copies are available, to teachers and librarians only, from the National Board of Fire Underwriters, 85 John Street, New York, N.Y., 10038.

A colorful poster, stressing the importance of preventing forest fires, can be valuable in teaching conservation and in suggesting creative art work. Single copies. American Forest Products Industries, 1816 North Street, N.W., Washington, D.C., 20013.

TEACHING SUGGESTIONS
(pp. 306–308)

Background: Following are some safety rules for the laboratory:

Chemicals. A laboratory is no place in which to eat or drink. Avoid any situation which may lead to any chemical's being taken internally. Most chemicals are poisonous.

Keep your face away from the work area. Protect your clothing and eyes by wearing rubber aprons and goggles or eye shields. Many chemicals "eat" holes in clothing. Spattering of liquids or flying particles from a shattering substance can cause serious eye injuries, cuts, and chemical burns.

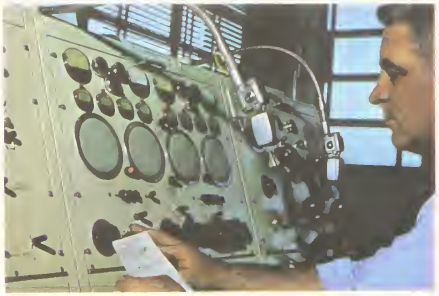
While pouring liquids, hold the bottle stopper or cork so that liquid will not get on the desk or other materials get on the cork.

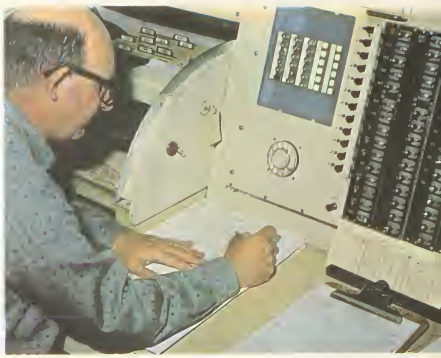
Traces of chemicals can cause some other materials to react or decompose rapidly.

When observing the odor of a substance, fan the gas toward your nose. Do not put your nose directly over the material. Some substances are poisonous; others can irritate the membranes of the respiratory system.

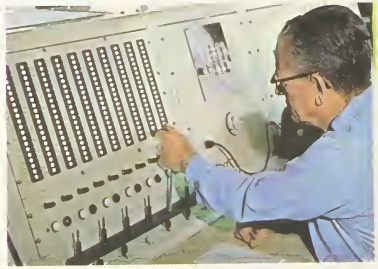
The dispatcher sends the alarm by a telegraph system to that zone. All the fire companies in the zone receive the alarm, but only those assigned in the area closest to Box 6035 respond.

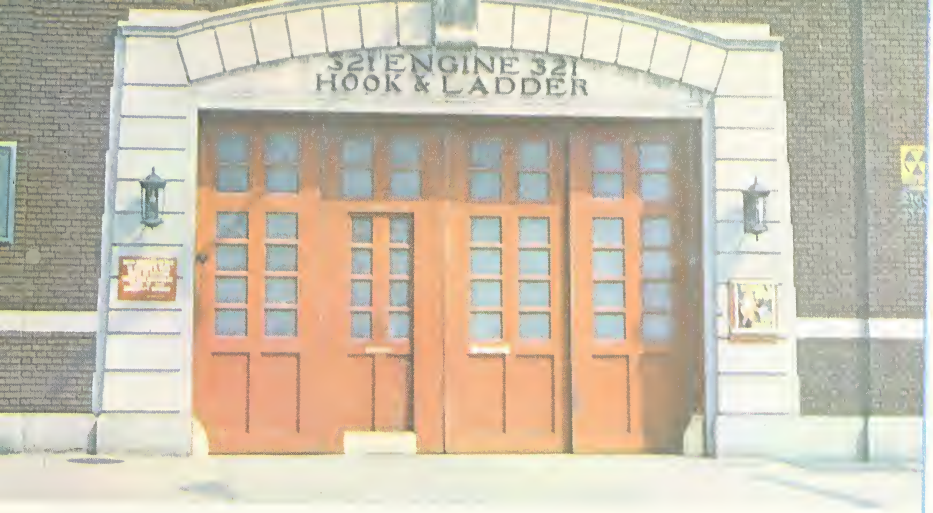
Then the dispatcher speaks by radio to the fire company.





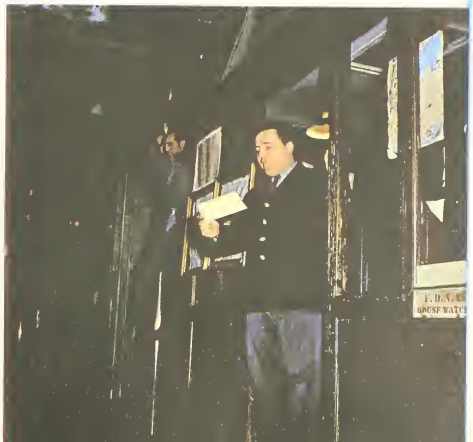
If the alarm is telephoned to the communications center, the exact address of the fire is known. The dispatcher telephones the fire company nearest to the address to respond.





At the fire station, the fireman on house watch pulls out the card for Box 6035 to find out its address.

He calls out the address as the firemen slide down the poles and get ready to leave.



Bunsen burners: Light the match, then turn on the gas. If too much air-gas mixture accumulates, an explosion can occur when a match is lighted.

Always have an approved fire extinguisher at hand when working with an open flame of any sort.

When lighting the burner, keep your face and other parts of the body to one side of the burner. Hair and clothing can be set on fire. Never reach over the burner.

Always apply heat gradually and evenly.

When heating a test tube, point the mouth of the tube away from yourself and others. As the liquid begins to boil, it may spurt out across the desk and burn someone.

Keep materials being heated at the back of the desk. If anything spills or breaks, there is less danger of personal injury.

When heating a test tube containing liquid, heat the contents by moving the burner flame up and down the outside of the tube.

Glassware: Most glass is a poor conductor of heat and has a high degree of expansion as the temperature increases. As glass is heated, it expands unevenly; it does not have a uniform temperature, because of its poor ability to conduct heat. This uneven expansion causes strains which make the glass break or shatter when heated directly. Glass may be heated in a water bath without breaking.

Pyrex, or fire-resistant glass, expands to a very small degree when heated. Therefore, it is not apt to break when direct heat is applied gradually.

Do not let anyone pick up glass that has been heated in a flame. Hot glass can cause very severe burns.

Glass that has been heated in a flame cools slowly. Set the hot glass on an asbestos pad to cool.

In a matter of seconds, the firemen are ready to go. In minutes, they will be at the scene of the fire. By this time, the communications center is in radio contact with the engines responding to the fire.

It takes only a few seconds for a fire to start, and just a few minutes for the firemen to get to the scene. But in that short time, lives and property could be lost forever.

Most fires can be prevented. That's your job. **Fire prevention is up to you.**

Using What You Have Learned

1. The fire department in your town saves many lives each year by putting out fires. Plan a visit to a fire station to find out how firemen get ready for their job. How do they plan their job so that no time is wasted in getting to a fire? How do they care for their equipment?
2. The fire drill in your school might save your life if a fire breaks out. Can you tell why? What rules are you expected to follow during a fire drill? Why are these rules needed?
3. Plan an exhibit to show what you have learned about fire. Show containers for materials that burn easily. Show some fireproof materials. Show pictures you have made of fire extinguishers and other ways of putting out fires. Make posters of rules for fire prevention.
4. Every year our nation suffers great losses because of forest fires that destroy lumber, homes, wildlife, and even human life. Make a report on ways to prevent forest fires and ways that forest fires are discovered and fought. A number of pupils may work together on this project.
5. Suppose that you are going down a street and you see smoke coming out the front door of a house. Which of these things would you do first? Why?
   a. Rush into the house to look for children.
   b. Wait till a man comes by and tell him.
   c. Find a policeman and tell him.
   d. Call the fire department.
   e. Walk by and say nothing about it.
   f. Call, "Fire!" as loudly as you can.

TEACHING SUGGESTIONS
(p. 309)

Background: The following will provide you with information for the *Using What You Have Learned* section.

1. The procedures here will vary with the community. Volunteer departments do not have resident firemen at the station as a general rule. Municipal paid departments do. In both instances warning bells, radio, telephone, and horns are used to alert and signal the location of fires. Most departments, volunteer and paid, keep the equipment in ready condition at all times.

2. Drill in learning is dull but productive. The lives of many depend on the actions of few in a large catastrophe such as exists in a fire situation. Commands and orders of firemen and teachers must be heard and executed with the utmost efficiency where only seconds can spell disaster. Automatic response is the result of drill.

3. Usually local fire departments sponsor poster and essay contests during Fire Prevention Week.

4. Show the film *Forest Ranger*. This is a 13 minute color film by Encyclopaedia Britannica.

5. F. should be the first response.

TEACHING SUGGESTIONS
(pp. 310–311)

Background: *The Safety Rules* illustrated on pages 310 and 311 are:

1. The young lady is heating a test tube containing a liquid. She is holding the tube with a proper test-tube holder. Furthermore the lip of the tube is pointed away from the face. To be perfectly safe no one should be opposite her in line with the lip of the tube. The lit bunsen burner is away from the girl at the back of the table where it belongs.

2. Notice the stopper! It is held in position between the middle fingers with the stopper grip, down, and stopper proper, up. This prevents burns to table top or materials on the table and also is an assurance that the bottle will be stoppered when the boy is finished pouring. A funnel should be used when pouring into a confined opening.

3. Where there is the danger of explosion or large quantities of noxious gases being produced, a fume hood with shatterproof glass is used. The operator uses safety goggles as an added precaution.

4. When testing for odor on a substance that is hot or poisonous NEVER sniff directly. The scientist wafts fumes toward him by waving his hand over the opening.

Safety in Science

You know that even ordinary household things can be dangerous if used carelessly. You must be careful to use them safely.

Always remember this rule: Never use any new material or equipment until your teacher has shown you how to use it properly and safely.

Now look at the pictures showing children doing science experiments and scientists at work. See how each person is working safely.

Can you tell what safety rules are being observed by the children and the scientists shown?

Using What You Have Learned

1. Make up a set of safety rules to follow whenever you do science experiments in your classroom or at home. Are there any ways in which your safety rules for home and those for your classroom might be different? Print your rules on a large piece of paper and hang them up in your classroom.

2. Send letters to large companies such as E. I. DuPont de Nemours in Wilmington, Delaware, and General Electric in Schenectady, New York. Ask about their safety programs for scientists and other workers.

Safety instructions for science teachers include the following:

1. Keep all bottles labeled at all times. If no other kind of label is available, a piece of adhesive tape will serve the purpose.

2. Liquids or solids found in unlabeled bottles should be discarded. Do not guess as to the nature of the substance.

3. Bottles containing acids or organic volatile liquids should never be placed near heating pipes nor allowed to stand in the sun; dangerous gas pressures may be built up.

4. Alcohol or other volatile liquids should not be used in a room where there is a flame, or where a flame may be used shortly thereafter. Rags or cotton swabs soaked in any of these substances should be carefully disposed of in fireproof receptacles.

5. Combustible materials of all types should be kept in a metal cabinet provided with proper means for closing and locking.

TEACHING SUGGESTIONS
(pp. 312–313)

Background: These two pages constitute a review of the concepts and terminology introduced in this lesson.

What You Have Learned: This is a summary of the entire unit, with new words in boldface type.

WHAT YOU KNOW ABOUT
Safety and Science

What You Have Learned

Children have accidents most often when they are playing. They have many different kinds of accidents. Some children have accidents with their bicycles. In order to ride your bicycle safely, you must obey all the safety rules and check your bicycle regularly to make sure it is in good condition. If you must ride your bicycle at night, you should wear light-colored clothing and have a headlight and a taillight on your bicycle.

Unsafe drinking water can cause you to become very sick. You can make water safe to drink by filtering it to take the dirt from it and then boiling it to kill the **germs.** Germs can also be killed by adding **chlorine** to the water. But even water that is safe to drink may not be pure water. Water must be **distilled** to be made pure. There are no plants, animals, or minerals in pure water. Playing in water can be great fun if you can swim, if the water is clean, and if there is an older person with you.

Fire that is out of control can cause many serious accidents. If you want to control fire, you must know what things a fire needs when it burns. You have learned that it takes three things to make a fire. There must be some material to burn, there must be oxygen present, and the material must be heated. The best ways to keep uncontrolled fires from causing damage is to prevent them from happening.

You should never use any new materials or equipment until your teacher has shown you how to use them. If you follow this rule, you can prevent accidents from happening in the classroom.

Checklist of Science Words

Here are some science words you read about in this unit. Can you tell what you have learned about each one?

acid	distill	germs
chlorine	fire prevention	

Another Survey

One class took a survey to find out what accidents happened most often to boys and girls. Look at the master list they made up. Now, number your notebook page from 1 to 5. Next to each number, write the answer to each question below.

1. What accidents happened most often?
2. What accidents happened least often?
3. How many children were hurt by falls?
4. How many children were hurt in bicycle accidents?
5. How many children were hurt by fire?

MASTER LIST OF MR. CLARK'S CLASS

These accidents happened most often to boys and girls in our class.

1. Falls	𝍸 𝍸 𝍸 𝍸 𝍸 𝍸	30
2. Swimming Accidents	𝍸 𝍸 𝍸	15
3. Poisonings	𝍸 𝍸 ||	12
4. Bicycle Accidents	𝍸 𝍸 𝍸 𝍸 𝍸	25
5. Fire Accidents	𝍸 𝍸	10

Checklist of Science Words: Remind the pupils that there is a *Dictionary of Science Words* on pages 318–325. They should consult this dictionary whenever they are unsure of the precise meaning of a word.

Another Survey:

1. Falls
2. Fire accidents
3. 30
4. 25
5. 10

TEACHING SUGGESTIONS
(pp. 314–315)

Unscramble the Letters:

1. Acid
2. Bicycle safety
3. Chlorine
4. Fire prevention
5. Distilled water
6. Germs

You Can Read: Your pupils might enjoy the following books.

Let's Be Healthy, by W. W. Charters, Dean F. Smiley, and Ruth Strang (Macmillan, 1955).

First Aid Textbook for Juniors, American National Red Cross (Blakiston, 1957).

Teachers interested in pursuing the problems of laboratory safety may obtain additional information from the National Safety Council, 425 North Michigan Ave., Chicago, Illinois, 60611, and the Campus Safety Association, care of W. W. Joy, University of Michigan, Ann Arbor, Mich.

YOU CAN LEARN MORE ABOUT

Safety and Science

Unscramble the Letters

1. It is found in a fire extinguisher and is like very, very strong vinegar.
2. This kind of program can reduce serious accidents.
3. This is put in swimming pools and drinking water to kill germs.
4. The best way to keep fires from starting.
5. Water that has been boiled and condensed to make it pure.
6. We boil water to kill these living things.

1. DIAC
2. ECLIBYC EFASYT
3. RONICHLE
4. EFIR NTIRPEVEON
5. SLITELDID TRAWE
6. REMGS

You Can Visit

A water purification plant is a place where water is purified and tested.

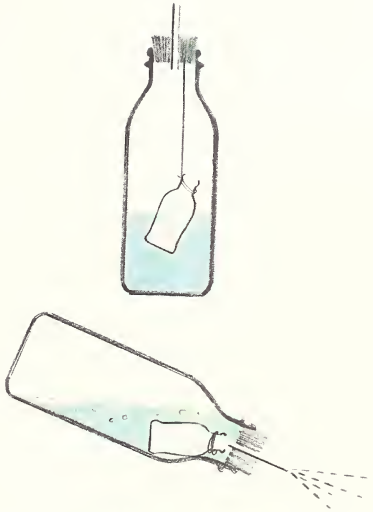
If there is a water purification plant near your school, perhaps your class can arrange to visit it.

You should make up a list of questions to ask the scientists at the plant. You might ask them such questions as: "How do you filter the water? Where does the water come from? What chemicals do you add to the water to make it safe to drink?"

Make a Fire Extinguisher

You will need a milk bottle, a rubber stopper with a hole, a glass tube, a glass pill bottle, vinegar, water, baking soda, and a thin wire.

Mix the baking soda and water together and put them into the milk bottle. Fill the pill bottle with vinegar. Then wrap the wire around its neck. Push the glass tube through the hole in the rubber stopper. Stick the loose end of the wire firmly into the rubber stopper. Place the glass tube into the hole in the rubber stopper. Hang the pill bottle in the milk bottle. Press the rubber stopper tightly into place. You now have a fire extinguisher. When you turn it over, water will spray out.



You Can Read

1. *Safety in Family Living* by the National Commission on Safety Education, Washington, D.C.
2. *School Playground Safety* by State Department of Public Instruction, Lansing, Michigan.
3. *How to Make Your Home a Safe Place* by Metropolitan Life Insurance Company, New York, New York.
4. *Your Safety Handbook* by N. Dearborn and W. Andrews. Safety measures to observe at all times.
5. *Watch Your Step* by J. J. Floherty. How to avoid accidents.

Films:

City Water Supply (11 min., b/w, EBF). Reviews man's dependence on water for life and emphasizes the problems involved in obtaining an adequate and safe city water supply. Illustrates sources available to New York City. Reveals the engineering accomplishments which have made it possible to bring water from its source and distribute it.

Dams (14 min., color, Pat Dowling). The multiple purposes of dams, explained in this film, include the creation of electric power, storage of water for agricultural and domestic use, flood control, improvement of inland waterways, repelling salt-water intrusion, and providing recreational areas. Dam construction, operation of a power plant, and a system of canals are seen.

Fire (11 min., b/w, EBF). Describes domestic uses of fire and explains the principles of combustion, the nature of fire hazards and the principles of extinguishing fire. Reveals how combustion is affected by the regulation of the draft in a furnace, and of gas and air in a stove.

A Visit to the Waterworks (11 min., b/w, EBF). Shows an elementary school class being taken on a tour of the local waterworks.

MATERIALS CHECKLIST

Unit 1	MATERIALS CHECKLIST	QUANTITY	DATE NEEDED	SOURCE
	strings, wires, or chains of different lengths (2 of each)			
	balls of different weights, such as rubber balls, golf balls, or baseballs (2 of each)			
	a watch with a second hand			
	tacks			
	pen or pencil and some paper			
	light meter			
	large cardboard box			
	electric lamp			
	sheets of paper (different colors)			

Do You Remember?

Energy has many forms. One of these forms is *electricity*. Electricity can do work. Every one of the *electrons* and *protons* that make up an *atom* carries a charge of electricity. The electron carries a *negative charge* (−), and the proton carries a *positive charge* (+). Charges that are alike (++ or −−) push away from each other. Charges that are not alike (+− or −+) pull toward each other.

There are two kinds of electricity—*static electricity* and *current electricity*. Static electricity is electricity that is at rest on an object. Current electricity is electricity that moves along a path. Current electricity can be run through wires. It does a great deal of work that is useful to man.

Another form of energy is *sound*. Sound can do work. Sound is made when something *vibrates*. The number of times an object vibrates is called its *frequency*. *Pitch* is the name for how low or how high a sound is. The higher the frequency, the higher the pitch. We can also change the pitch of a sound by changing the thickness, the length, or the *tension* of the object. Musical instruments are a good example of the way thickness, length, and tension affect pitch.

Light is a form of energy. It can do work. When the energy of light strikes certain cells in your eyes, you can see. Light enters the eye through the *cornea*. From there it goes through an opening called the *pupil*. The size of the pupil is controlled by the *iris*. The light then passes through the *lens*. The lens *focuses* the light, first through a colorless liquid, and then onto the *retina*.

You have learned how scientists make *comparisons* to learn more about the many forms of energy. Making comparisons and knowing about the forms of energy enables weather scientists to *forecast* the weather more accurately. The weatherman must know how changes take place in *temperature, air pressure,* and *water vapor* in the air. He must also know what causes these changes.

Knowing about energy and its forms is not enough. Energy must be used safely. Energy can be very valuable to man, but the energy of fire, water, and moving objects can be dangerous, too. If you are careful, you can prevent accidents. For example:

1. To prevent bicycle accidents, you must watch and obey traffic signals. Obey the bicycle safety rules and check your bicycle brakes often.
2. To prevent accidents in the water, you must remember to swim only in clean water, and only when an adult is there to watch you.
3. To prevent fires, you must remember that fire needs air, heat, and material in order to burn.

You have learned about different kinds of energy. You have learned how one kind of energy is captured by green plants, and how it is used by these plants and then by animals. You have learned about three important forms of energy: electricity, sound, and light. You have read about the forces that shape our weather, and lastly you have seen that it is important for you to learn to use energy safely.

MATERIALS CHECKLIST

Unit 2

- bicycle pump
- bicycle
- broom handle or stick
- pile of books
- long, heavy string
- 2 pencils
- chair
- a watch with a second hand
- old inner tube
- chalk or other marker
- stones, sand, bits of paper or anything you wish to weigh
- toy pail
- water

MATERIALS CHECKLIST

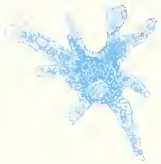
MATERIALS CHECKLIST	QUANTITY	DATE NEEDED	SOURCE
Unit 2 (cont.) heavy string			
shallow pan			
marbles			
ruler or tape measure			
mud			
ladder			
long, narrow tube of polyvinyl (3 feet, if possible)			
heavy-weight oil to fill the tube			
metronome			
strip of cardboard as long as the tube			
2 yardsticks			

Dictionary of Science Words

A

acid. The liquid used in a fire extinguisher. Acid is like vinegar, but it is much stronger. There are many other kinds of acid that can be used in many other ways. (p. 292)

ameba (uh-MEE-buh). A one-celled animal that is so small you cannot see it unless you use a microscope. Amebas live only in water. (p. 116)



anemometer (an-uh-MOM-uh-ter). A weather instrument used to measure the speed of the wind. (p. 239)

atoms. The particles from which all matter is made. (p.141)

B

barometer (buh-ROM-uh-ter). A weather instrument used to measure air pressure. One kind of barometer is the mercury barometer. (p. 244)

biologist (by-OL-uh-jist). A scientist who studies living things. (p. 115)

biology (by-OL-uh-jee). The study of living things. (p. 115)

blind spot. The part of the retina where there are no cones or rods. There is no vision at the blind spot. (p. 212)

bulb. The round, thick part of such plants as the onion and tulip. Bulbs grow in the soil and have food stored in them. (p. 73)

C

cell. A tiny unit of living matter. All living things are made of cells. (p. 105)

chlorine (KLOR-een). A chemical put into water to kill germs. (p. 285)

chlorophyll (KLOR-uh-fil). The green chemical found in green plants. Chlorophyll is used by these plants to make food. When the sun shines, the plants with chlorophyll can change carbon dioxide and water into glucose. (p. 62)

chrysamoeba (KRISS-uh-mee-buh). A tiny living thing that is often found in ponds. It makes its food by photosynthesis, as a green plant does. But it can also eat food that it does not make itself. In this way, the chrysamoeba is somewhat like an animal. (p. 112)

circuit (SER-kit). The unbroken path of an electric current. A circuit is made whenever electricity leaves a source and then returns to the same source. (p. 156)

closed circuit. An electric current that leaves a source and then travels along an unbroken path back to the same source. (p. 156)

comparison. A way of telling how things are alike and how they are different. (p. 2)

complicated animal (KOM-pluh-kayt-id). An animal with many different parts. (p. 116)

condensation (kon-den-SAY-shun). The changing of water vapor to liquid when the air is cooled. (p. 248)

conductor (kun-DUK-ter). A material that makes a good path for an electric current. Most metals are good conductors. (p. 149)

cones. Cells in the retina that help you see colors and small objects. (p. 210)

connective cells (kuh-NEK-tiv). Cells that connect other cells together. (p. 119)

controls. The things that you keep the same in an experiment. (p. 11)

cornea (KOR-nee-uh). The clear outside covering of the eye. Light enters the eye through the cornea. (p. 204)

current electricity (KUR-ent). Electricity caused by electrons moving through a path or wire. Electrons enter, travel through, and pass out of a conductor. (p. 149)

D

degrees. The marks on an instrument which are used for measuring. Degrees on a thermometer show you how hot or cold a thing is. (p. 247)

MATERIALS CHECKLIST

Unit 2 (cont.)

- empty spool for thread
- coat hanger
- long, heavy rubber band
- stones
- empty chalk box
- small square of wood (about ½" thick)
- glue
- sandpaper
- balloon
- wax
- water
- piece of glass
- oil

MATERIALS CHECKLIST

MATERIALS CHECKLIST	QUANTITY	DATE NEEDED	SOURCE
Unit 2 (cont.)			
potholders			
insulated wire			
crowbar			
screwdriver			
pliers			
1' x 2' piece of wood			
6 empty spools			
7 nails			
small cardboard box			
2 pieces of string			

distilled water (dih-STILD). Water that is heated until it becomes water vapor, and then cooled until it becomes liquid again. Distilling removes the dirt and germs from the water. (p. 285)

dry cell. A metal can which makes an electric current. The can is filled with a material that is like paste. (p. 149)

E

echo (EK-oh). A sound that you hear more than once because the sound waves bounce back. (p. 189)

electricity (ih-lek-TRISS-ih-tee). A form of energy. Electricity can push or pull things. One kind of electricity is current electricity. Another kind is static electricity. (p. 22)

electromagnet (ih-lek-troh-MAG-nit). A piece of metal with a coil of wire around it. The metal becomes a magnet when an electric current flows through the coil. (p. 159)

electron (ih-LEK-tron). A particle that moves around the nucleus of an atom. The electron has a negative charge. (p. 141)

energy. The ability to do work. There are many kinds of energy, such as electricity, heat, light, and sound. (p. 22)

energy in action. Energy that is doing work. (p. 25)

euglena (yoo-GLEE-nuh). A tiny living thing that is often found in ponds. It can swim, like animals, but it can also make its own food, like green plants. (p. 112)

evaporation (ih-vap-uh-RAY-shun). The escape of water molecules into the spaces between the air molecules. (p. 247)

experiment. The scientist's way of seeking proof for ideas, by measuring and comparing things and by using controls. (p. 2)

experimental factor (ik-sper-uh-MEN-tul FAK-ter). The one thing that is different in an experiment. (p. 11)

F

Fahrenheit (FAR-un-hyt). The scale on some thermometers. (p. 247)

fertilizer (FER-til-yz-er). A material that is put into the soil to help plants grow better. Fertilizers are rich in important minerals. (p. 94)

fire prevention. Making sure that fires do not start in places where you do not want them. (p. 296)

focusing (FOH-kuss-ing). The moving of a lens to change the direction of the light. Focusing the light helps the eye to see objects more clearly. (p. 206)

force. A push or a pull on an object. Energy is needed to produce a force. (p. 28)

forecast (FOR-kast). To tell what the weather will be like. (p. 224)

fovea (FOH-vee-uh). The place near the center of the retina where there are only cones. (p. 211)

frequency (FREE-kwen-see.) The number of times that an object vibrates each second. (p. 175)

friction (FRIK-shun). The rubbing of one thing against another. Friction produces heat. (p. 44)

fungi (FUN-jy). Plants that are not green and which do not have any chlorophyll in them. Fungi do not make their own food. (p. 79)

fuse (fyooz). A piece of metal which opens a circuit when too many electrons are going through the circuit. (p. 164)

G

germ. A tiny living thing that can cause disease. (p. 281)

glucose (GLOO-kohss). The sugar that is made by plants during photosynthesis. (p. 64)

gravity (GRAV-ih-tee). The force that pulls things toward the earth. (p. 37)

H

humus (YOO-muss). Plant and animal material that has decayed. Humus adds minerals to the soil. It helps the soil to hold more water and keeps the soil from becoming dry and hard. (p. 91)

hydra (HY-druh). A tiny simple many-celled animal with tentacles which is found in streams and ponds. The hydra gets its oxygen from the water. (p. 118)

I

instrument (IN-stroo-ment). A tool that scientists use, such as a barometer or microscope, to measure and do other things more accurately. (p. 2)

MATERIALS CHECKLIST

Unit 3
wide-mouthed glass jar and cover
small glass bottle
hot plate
rubbing alcohol
green leaves (coleus or geranium)
iodine
tweezers
medicine dropper
corn seeds or bean seeds
blotting paper
pan of water
two pieces of glass
string
a carrot or a sweet potato

MATERIALS CHECKLIST

MATERIALS CHECKLIST		QUANTITY	DATE NEEDED	SOURCE
Unit 3 (cont.)	knife			
	celery			
	red or blue vegetable coloring			
	onion			
	narcissus and hyacinth bulbs			
	pebbles or stones			
	2 or 3 pieces of charcoal			
	4 flowerpots of the same size			
	wire screening			
	cheesecloth			
	grass			
	different kinds of soil			

insulator (IN-suh-lay-ter). Any material that does not allow electricity to move freely through it. Rubber and glass are insulators. (p. 150)

iris (EYE-riss). The circle of color in the eye. The iris is a muscle which controls the amount of light that enters the pupil of the eye. (p. 205)

L

lens (lenz). A part of the eye between the pupil and the retina. Light enters the eye through the pupil and is then focused by the lens onto the retina. (p. 205)

lever. A simple machine that can be used to lift or move an object. A lever is a bar which you push down on one end so that you can raise an object at the other end. A crowbar is an example of a lever. (p. 31)

life activity. One of the things plants and animals do to stay alive, such as using food and oxygen, producing more living things like themselves, and getting rid of wastes. (p. 104)

life history. The way in which each plant and animal lives and grows. (p. 83)

light. The form of energy that lets you see. (p. 221)

light receiver cells. The rods and cones in the retina of the eye. These cells receive the light after it has traveled through the lens. (p. 210)

loam. A type of soil that is made of sand, clay, and humus. Loam is the best soil in which to grow plants. (p. 91)

M

matter. Anything that fills space. (p. 140)

mechanical energy (muh-KAN-ih-k'l). The energy of moving things. (p. 25)

mercury barometer (MER-kyoo-ree buh-ROM-uh-ter). A weather instrument used to measure air pressure. When air pressure increases, mercury is pushed up. When it decreases, mercury goes down. (p. 244)

molecules (MOL-uh-kyoolz). The very small parts that make up the air. Most things are made of molecules. (p. 231)

muscle cells. Long, stringy cells that are held together by connective cells. (p. 120)

N

negative charge. The — charge of an electron. A negative charge pulls toward positive proton charges and pushes away from other negative electron charges. (p. 142)

nerve cells. Cells that receive messages and then send the messages to other cells. (p. 119)

neutron (NOO-tron). One of the particles in the nucleus of the atom. The neutron has no charge. (p. 141)

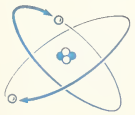
O

open circuit (SER-kit). A circuit which is not complete. There is no flow of current electricity. (p. 156)

opaque. A word describing any material through which light will not pass. (p. 202)

ophthalmic surgeon (ahf-THAL-mik). A doctor who operates on the human eye. (p. 214)

orbit (OR-bit). In the science dealing with electricity, this term refers to the path that an electron makes around the nucleus of an atom. (p. 144)



P

parallel circuit (PAR-uh-lell SER-kit). A circuit in which all the lights do not go out when one of the lights goes out. They do not all go out because the circuit is not broken. (p. 156)

photosynthesis (foh-tuh-SIN-thuh-siss). The making of food, by green plants, from carbon dioxide, water, and sunlight. (p. 63)

pitch. How high or how low a sound is. (p. 183)

porous (POR-uss). Full of tiny air spaces and therefore able to absorb sound waves. (p. 191)

positive charge. The + charge of a proton. A positive charge pulls toward negative electron charges and pushes away from other positive proton charges. (p. 142)

proton (PROH-ton). One of the particles in the nucleus of an atom. The proton has a positive charge. (p. 141)

pulley (PULL-ee). A simple machine that is used for lifting objects. It is made with a wheel, an axle, and a rope. By pulling one end of the rope, an object tied to the other end can be lifted. (p. 33)

MATERIALS CHECKLIST

Unit 3 (cont.)	a few tin cans pan electric hot plate blue litmus paper plants of different sizes twigs and bark nuts pine cones aquarium tank	
Unit 4	earthworms insects such as ants, ladybugs, or butterflies hydras	

MATERIALS CHECKLIST

MATERIALS CHECKLIST		QUANTITY	DATE NEEDED	SOURCE
Unit 4 (cont.)	amebas aquarium medicine dropper water glass slide cover slide			
Unit 5	2 plastic combs piece of fur 2 glass rods piece of silk string			

pupil. The small black circle in the eye, really the space inside the eye. The size of the pupil is controlled by the iris. (p. 204)

R

rain gauge. An instrument used by weather scientists to measure the amount of rainfall. (p. 224)

reflected waves. Waves which are bounced back. An echo is the result of reflected waves. (p. 188)

retina (RET-ih-nuh). The inside part at the back of the eyeball which has cone cells and rod cells in it. The retina receives the light from the lens. (p. 209)

rods. The cells in the retina that help you to see better when the light is dim. (p. 210)

S

scale. All the evenly spaced marks along an instrument, which are used for measuring. (p. 247)

series circuit (SEER-eez SER-kit). A circuit in which all the lights go out when one of the lights goes out. They all go out because the circuit is broken. (p. 156)

short circuit (SER-kit). A circuit that has been broken. In a short circuit, the wires touch and the electrons flow along a shorter path. (p. 161)

simple animal. An animal with few parts, such as an ameba or a hydra. (p. 116)

sound. A form of energy. Sound is heard when an object vibrates fast enough. (p. 22)

soundproofing materials. Porous materials that are used to absorb and control noises and echoes. (p. 192)

sound waves. The waves that travel through material and cause you to hear. (p. 177)

static electricity. Electricity that is made by friction. Static electricity does not move along a path. It jumps from one object and then rests on the object on which it lands. (p. 148)

stored energy. Energy that is not doing work. A match has stored energy. (p. 25)

survey (SER-vay). A way of looking for information in different places and keeping a written record of what you find. (p. 109)

system of classification. A way of sorting things into groups so that you know where each thing belongs. Scientists use the binomial system to classify living things. (p. 122)

T

tension (TEN-shun). The tightness or looseness of any object that can be stretched. A change in tension can make a vibrating object change its pitch. (p. 186)

tentacles (TEN-tuh-kulz). Long, stringy arms used for feeling, holding, or moving. The hydra is an animal that has tentacles. (p. 118)

translucent. A word describing any material that lets light enter and then scatters it. (p. 202)

transparent. A word describing any material that allows light to pass through it freely. (p. 201)

U

ultrasonic sound (ul-truh-SON-ik). A sound that you do not hear because the object is vibrating more than 20,000 times each second. (p. 176)

V

vaporization (vay-per-ih-ZAY-shun). The changing of a liquid into a gas. In water vaporization, the water changes into a gas called water vapor. (p. 285)

vibrate (VY-brayt). To move back and forth quickly. (p. 173)

vibration. A quick back-and-forth movement. (p. 173)

W

water vapor. Very tiny particles of water in the air. You cannot see water vapor because it is a gas. (p. 224)

weather station. A place where scientists forecast the weather. They use instruments there to measure such things as temperature, air pressure, rainfall, and the speed of the wind. (p. 224)

weed. A plant that grows where you do not want it. (p. 81)

wind. Air that is moving. (p. 229)

work. Moving something by pushing or pulling it. When something is being moved, work is being done. (p. 22)

MATERIALS CHECKLIST

UNIT 5

- 2 balloons
- piece of wool
- nylon stocking
- clear plastic bag
- 8″ x 10″ paper
- piece of glass
- 2 books
- bits of paper (1/2″ x 1/2″)
- scissors
- 8 clean pennies
- 8 clean dimes
- sandpaper
- paper tubes for pennies
- blotting paper

MATERIALS CHECKLIST

MATERIALS CHECKLIST	QUANTITY	DATE NEEDED	SOURCE
Unit 5 (cont.)	glass of water cellophane tape 2 six-inch wires non-working dry cell tool to open dry cell 2 pieces of metal hole puncher for metal wooden block screws 2 flashlight dry cells piece of paper, long enough to cover dry cells		

Dictionary of Scientists

Here is a list of the scientists you have read about in this book.

Aristotle (AR-iss-tot'l). A famous Greek scientist. His studies prepared the way for other scientific discoveries. He gave his own wide knowledge and experience to the scientists who came after him. (pp. 4, 12)

Boyle, Robert. The English scientist who discovered that sound waves cannot travel where there is no air. (p. 176)

Cooper, Irving S. A medical doctor who found that he was able to help patients with Parkinson's disease by freezing portions of their brains. (p. 214)

Fahrenheit, Gabriel Daniel (FAR-un-hyt, GAY-bree-el DAN-yell). The German scientist who made up the scale called the Fahrenheit scale, now used on certain thermometers. (p. 247)

Galilei, Galileo (gal-uh-LAY-ee, gal-uh-LAY-oh). An Italian scientist who was one of the first men to seek experimental proof for his ideas. (p. 4)

Ingen-Housz, Jan (ING-un-howss). The Dutch scientist who did the first research in photosynthesis. (p. 64)

Joule, James. The English scientist who showed that when one form of energy is changed into another, no new energy is created and no old energy is destroyed. (p. 26)

Kelman, Charles D. An eye surgeon who has experimented with cryosurgery (cold surgery). (p. 214)

Leverrier, Urbain (leh-vehr-ee-AY, ur-BAN). The French scientist who made the plan for the first international telegraph system. (p. 227)

Lincoff, Harvey, and associates. The medical doctors who first used cryosurgery (cold surgery) to heal detached retinas. (p. 214)

Lining, John (LYN-ing). A medical doctor who was the first to keep careful and correct records of the daily weather where he lived in America. (p. 225)

Linnaeus, Carolus (lih-NEE-uss, KAR-uh-luss). The Swedish scientist who made up the binomial system of classification for all plants and animals. (p. 128)

Morse, Samuel F. B. The American scientist who, in 1837, invented the telegraph. (p. 226)

Potts, William L. A traffic engineer who set up the world's first four-way traffic-signal tower. (p. 266)

Rabinowitz, Eugene. A botanist whose study of green plants may some day help scientists to make photosynthesis happen without the use of plants. (p. 65)

Reichelderfer, Francis W. The former United States chief weatherman whose work helped the U.S. Weather Bureau offer many new services in weather forecasting. (p. 228)

Volta, Alessandro (VOHL-tah, ah-leh-SAHN-droh). The Italian scientist who built the first electric cell. (p. 150)

MATERIALS CHECKLIST ✓

Unit 5 (cont.) bell wire flashlight bulb 3 rubber bands nails wire salt and pepper piece of plywood 10 cup hooks 10 pieces of bell wire 10 alligator clips	Unit 6 ruler rubber bands drum

MATERIALS CHECKLIST

MATERIALS CHECKLIST	QUANTITY	DATE NEEDED	SOURCE
Unit 6 (cont.)			
dry cereal			
a rubber heel (or another piece of hard rubber)			
tuning fork			
small basin filled with water			
metal triangle			
alarm clock			
small ball or marble			
large ball or marble			
pan of water			
string			
ping-pong ball			

Checklist of Science Activities

Here is a list of some things you can learn to do as you read this book. At the end of each unit there are four pages that tell you other things you can do.

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Finding out which colors reflect the most light 14

2 Understanding Energy

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How can you measure the force of gravity? 35
How does height affect the force of a falling object? 40
Do things speed up as they fall? 41
Do things hit harder if they fall faster? 42
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How will knowing about friction help you travel more safely? 48
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3 Living Things—Green Plants

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What happens when things have like charges? 145
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MATERIALS CHECKLIST

Unit 6 (cont.)

- comb
- cardboard
- empty wooden chalk box
- long piece of wood
- saw
- rolled-up newspaper
- nails
- drinking glass
- paper towel
- tissue paper
- pad of writing paper
- aluminum foil
- cardboard
- empty pail

MATERIALS CHECKLIST

MATERIALS CHECKLIST	QUANTITY	DATE NEEDED	SOURCE
Unit 6 (cont.) 2 tin cans 2 buttons several feet of string			
Unit 7 desk lamp shoe box 2 pocket mirrors tape protractor razor blade drinking glass half-filled with water 2 chalkboard erasers			

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Testing materials to see if they are good conductors of electricity 157
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Does the sun heat all surfaces the same amount? 234
Are things of different colors heated equally fast by the sun? 235
Does being in the shade affect the temperature? 237
Finding out whether soil or water cools off faster 237
Making a weather vane 240
Making an exhibit or scrapbook on "Weather in the News" 241

MATERIALS CHECKLIST

Unit 7 (cont.)
few drops of milk piece of black paper flashlight magnifying glass large piece of white paper tacks brightly colored cards penny glass bowl filled with water sheet of paper rubber ball cardboard or a piece of wood different color paints cellophane

MATERIALS CHECKLIST
BOOK 4

MATERIALS CHECKLIST	QUANTITY	DATE NEEDED	SOURCE
Unit 8			
vegetable dye			
2 bottles			
pail of water			
2 glasses			
soil			
2 coffee cans			
thermometer			
large pieces of white, red, blue, and black cloth			
large piece of paper			
heavy cardboard			
compass			

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MATERIALS CHECKLIST

Unit 8 (cont.)

- paper clip
- needle
- drinking straws
- eraser
- pencil
- 2 balloons
- scissors
- small water-filled bottle
- rubber bands
- glass tube
- quart juice can
- hole puncher for metal
- modeling clay
- 12-inch ruler

MATERIALS CHECKLIST

MATERIALS CHECKLIST	QUANTITY	DATE NEEDED	SOURCE
Unit 8 (cont.)			
water			
tape			
crayon or piece of colored chalk			
ice cube			
cellophane bag			
cold plate			
pan with straight sides			
large glass jar			
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MATERIALS CHECKLIST

Unit 9	
	flashlight
	colored paper (several sheets)
	2 glasses of hot water
	¼ teaspoon salt
	filter paper
	water
	funnel
	2 glass jars
	garden soil
	salt
	teaspoon
	food coloring
	cooking pot
	egg

MATERIALS CHECKLIST

MATERIALS CHECKLIST	QUANTITY	DATE NEEDED	SOURCE
Unit 9 (cont.)	4 candles		
	4 pieces of metal		
	matches		
	4 jars (small jar, pint jar, quart jar, and very large jar)		
	3 lamp chimneys		
	4 pieces of wood		
	tablespoonful of baking soda		
	vinegar		
	hotplate		
	cup		
	milk bottle		

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Unit 9 (cont.)

glass pill bottle
one-holed rubber stopper to fit pill vial
glass tube to fit in stopper
thin wire

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TEACHERS' GUIDE FOR *BOOK 4*

TEACHERS' GUIDE FOR *BOOK 4*

Science for Tomorrow's World

BARNARD
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DELANEY

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In most elementary schools, it is the classroom teacher rather than a specialist in science education who teaches science. Thus, the classroom teacher must have some knowledge of the subject matter of science as well as an awareness of how children learn. The Teachers' Guide of *Science for Tomorrow's World* provides help in both of these areas. We include supportive factual information to strengthen what the teacher already knows about science, as well as teaching suggestions based on the present knowledge of how children learn.

To be truly effective as a teacher of science, the teacher must have an understanding of what science *is* and what a scientist *does*. We often hear that the American child of today is growing up in a scientific age. What does this really mean? What exactly *is* sci-

What's Ahead?
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2 Cells, Tissues, Organisms
Pathfinders in Science Severo Ochoa and Arthur Kornberg
3 Growth and Development
OBSERVATION
How Can the Wave Theory of Light Explain Reflection?
What You Will Need
How You Can Find Out
Questions to Think About
Putting Electrons to Work
Dictionary of Science Words
Dictionary of Scientists
You Can Visit
Conservation in Act

ence? The answer to this last question will determine the teacher's approach and orientation to every lesson presented. To help the teacher gain a fuller understanding of the climate of our scientific age, we begin the Teachers' Guide with a discussion of the meaning of science and the work of the scientist.

SCIENCE AND THE SCIENTIST

Science is the study of natural phenomena; it concerns itself with describing such phenomena and attempting to explain them through laws that constantly can be tested and corrected against consequences in experience. These scientific laws are then fitted into a working model of the universe—a model that may be in the form of an idea, a diagram, or a construction (Book 6, p. 145). Often, scientists must do many experiments before a working model can be developed. Often, too, many experiments and much theorizing are done after the model is developed, in order to determine whether or not the model is accurate. An accurate working model may be highly useful in predicting future events. With a working model of the solar system, for example, it is possible to make predictions about when eclipses will occur, when Mars will be closest to the earth, when tides will be high, and where the earth will be in relation to other planets at any given time in the future. In some instances, a working model also helps to control man-made or natural phenomena. A model of motion that approximates natural motion is indispensable in controlling man-made motions such as those of a primitive ox-cart or a modern space satellite. This is not to imply that science is concerned with prediction and control for practical reasons only. Such concern has grown out of man's need to dispel uncertainty, to know the world in which he lives.

In constructing a foundation for a model of reality, the scientist uses ideas of time, space, matter, causality, and number. In each of these areas, the scientist believes there is order; things do not happen in a haphazard fashion in the world of nature, but in a logical, noncontradictory manner. Thus, no matter what year, no matter what season, the sun always appears at dawn in the east. No matter what kind of projectile is launched from the earth into space, the projectile has two kinds of motion—a forward motion in the direction in which it was launched and a downward motion in the direction of the center of the earth.

From the dawn of history, man has sought to explain what he observed and then to use his explanations to predict future events. Even long ago, scientists believe, man was able to predict certain natural phenomena. They believe that an ancient people at Stonehenge, England, studied the movements of earth and sun and were able to place great rocks in such a fashion as to predict the beginning and ending of seasons and eclipses. We can find countless other examples to show that the order in the universe became evident to man's intelligence and that he used the test of prediction to prove the existence of that order. For example, at Stonehenge, it is believed that if ancient man's notions about movements of sun and earth were wrong, the sun would not have been seen rising over a particular stone on a particular day of the year; thus, the concept would have to have been changed accordingly. Sometimes when ancient man was unable to find an explanation for natural phenomena, he resorted to magic. Through magic, he thought himself able to explain a particular event, not by recourse to natural laws, but by the invention of uncontrollable "somethings" that he believed might yield to magical rites.

Why did man gradually give up magic and turn more and more to a search for natural laws? Psychologists find the explanation in the part of man's biological inheritance that is intelligence—a form of mental adaptation that causes man to seek to deal effectively with his environment. This basic need produces a tendency to give up explanations that do not conform to reality. Reality comes to be not what one perceives with the senses, but rather the product of trans-

formations that one performs upon data in the mind. A distant elm may appear to be smaller than a nearby birch sapling, but the mind puts each tree in proper spatial perspective. It may have seemed to ancient man that the sun traveled around the earth, but such a concept of the solar system is not consistent with all the known facts, and so man eventually constructed a more realistic concept of the solar system.

It is evident that science involves more than just the accumulation of new facts about the universe. Galileo's "facts" about motion are already known to anyone who has rolled an object down an inclined plane or thrown an object from a moving vehicle. All the facts needed to derive the concept of gravitation were known to man long before Newton. The great forward leaps in science have often come about not because man discovered new facts about the universe, but because a great scientific mind saw those same facts in a new framework. The search for new facts goes on continuously in scientific laboratories, but the major breakthroughs take place inside the minds of scientists themselves.

How do these breakthroughs occur? What does man look for to make the world more intelligible? Two guiding principles stand out: Man looks for *unity,* and he looks for *simplicity.*

To look for unity means to look for likenesses, often in unexpected places. It means, for example, seeing that the model of the solar system might also serve as a model for the atom. It means seeing similarities among the ant, the fish, the mouse, and man. For convenience, man may divide science into the study of the physical and the biological—the living and nonliving. But man searches for more than merely a similarity between any two related facts; he searches for a law that will explain *all* such related facts, and thus he strives toward unity.

The second guiding principle in man's striving to make the world more intelligible is that of simplicity. Man seeks the basic units—ultimate and fundamental units—out of which more complex matter is built. The discovery of the cell and the discovery of the atom were two milestones in man's striving toward simplicity. Present-day explorations of molecular activity in the cell lead further in the direction of unity and simplicity; eventually, the activities of all living things may be explained in terms of atoms.

In preparing *Science for Tomorrow's World,* the authors have been guided by a modern viewpoint of science. We have constantly asked ourselves what this modern viewpoint implies for science education in elementary schools. We turn now to a consideration of those implications which have guided our thinking in the planning and developing of this series.

A PHILOSOPHY OF SCIENCE EDUCATION

Three basic principles form the foundation of our approach to science education. First, we affirm our faith in the *natural curiosity of the child as a powerful motivating tool in acquiring science knowledge.* We believe that this curiosity can be kept at a high level, not necessarily by the use of bizarre or dramatic science activities, but by making explicit to the child the difference between his own view of reality and reality as it actually exists—as well as man can conceive of it. The child brings with him to the classroom a tremendous body of cognitive structures that he uses to explain the universe. The problem in teaching science to children is not that the child does not have explanations for natural phenomena; it is rather that his explanations are often either half-correct or wholly incorrect. Yet, if we can assume on the part of the child a basic urge to deal effectively with his environment, when he becomes aware of the discrepancy between what he believes and what is reality, we can then conclude that he will be more ready to apply the use of logic in his thinking. Here, both deductive and inductive (discovery) processes are invaluable. Some key concepts can best be taught by direct presentation that

is followed by applications of the key concepts to a wide variety of data. Thinking can be stimulated when the teacher says, for example, "How does what we have learned about sound apply to a mammal such as the bat? How can the bat's sense of hearing help the bat to know when an object is near?"

The discovery method is most effective when reserved for the induction of certain general laws. For example, in the study of animal behavior, children can discover for themselves some of the relationships between temperature and behavior. They can observe what happens to the behavior of a goldfish when the temperature of the water in the aquarium is lowered; they can note the movement of insects that have been placed in a box that is heated at one end. In the study of light, however, we cannot expect young pupils to use the inductive process to arrive successfully at the wave theory of light. Thus, deductive and inductive methods of presenting material have been used both selectively and realistically in *Science for Tomorrow's World* to achieve a maximum challenge to pupils' intellectual curiosity.

The second basic principle we accept is that *the elementary school child should gradually build a structure of science approximating the structure developed by the scientist.* Sometimes, in an effort to simplify subject matter, teachers have introduced erroneous concepts on the supposition that these concepts were easier for the child to understand. One such teacher taught that "Some insects lay eggs that hatch into worms"; he did this because he thought that "larvae" was too difficult a word to introduce to his second-grade class. It is possible, of course, to teach such a concept without actually using the word for the concept. But most important is that *the concept be accurate.* The biologist puts worms into a phylum that is completely separate from the phylum for insects; to say that larvae are "worms" puts a mistaken emphasis upon unimportant similarities in the appearances of the larvae and worms. We believe that a selection of simple but significant concepts can be taught so that even the young child has some exposure to the main ideas that structure a particular field of science. We also believe that children should know of man's long and continuing struggle to structure his knowledge—of the wrong turns he has made at times, and of how difficult it is to give up erroneous concepts even in the face of their inefficacy. Children should know and experience the exploration of the unknown, and they should also attempt to search for coherence in the world around them. Only then will they gain a perspective of science as man's attempt to decipher the code of the universe.

We have emphasized repeatedly man's basic tendency toward equilibrium—his need to resolve cognitive disturbance by accepting those ideas that fit with reality. But, as the history of science so dramatically illustrates, there is at the same time a strong tendency to resist change, to cling to cherished notions. In teaching science, we must not present a picture of the scientist as a kind of superman who readily accepts evidence that contradicts his own way of thinking. Part of the subject matter of science is the history of science; studying the history helps pupils to see the scientist as a human being, one who has had to engage actively in the process of accommodating to new theories—a process as difficult for him as for all other men.

The third principle we accept is that *the acquisition of knowledge can enhance logical thinking when proper attention is paid to processes.* The child becomes more logical in his thinking when he acts upon the data he assimilates, putting two and two together, making analogies by a one-to-one correspondence between parts, seeing the implications of one action upon another, setting up alternative hypotheses ("It's either this or that"), excluding variables that check out to be irrelevant. An important part of the teacher's responsibility in teaching science is to help the child acquire mental processes for transforming data so that

inconsistencies in thinking can be eliminated and reasoning can become more logical.

In teaching elementary school science, much has been made of the scientist's sequential method of searching for truth—of observing, hypothesizing, testing, noting results, drawing conclusions. Each of these activities is an important scientific activity, but note that the scientist does not necessarily proceed step by step from one activity to the next. Thus, observation is part of *every* scientific activity; or, a scientist in the process of testing may observe that a certain phenomenon does not conform to what he thinks ought to be happening, and as a result he may start off on a new and perhaps more important track. The elementary science curriculum ought to describe the scientist's methods. But in order to ferret out contradictions, in order to make children "think like a scientist," we need to emphasize (1) logical thinking, (2) the habit of testing concepts, and (3) the checking of concepts against their consequences in experience. To teach children a pat process is not the answer; we will return to this point later in our discussion.

The child, the structure, the processes—these are the foundation stones of *Science for Tomorrow's World*. While we deal with structure and processes in succeeding sections, there is no separate section on the child; consideration of the learner is woven into every section.

THE STRUCTURE OF SUBJECT MATTER IN THE ELEMENTARY SCIENCE CURRICULUM

In building a curriculum, the first obvious question that we ask is, "What is considered important for children to learn in the field of science?" With man's knowledge expanding at a fantastic rate, it becomes increasingly necessary to exercise great selectivity in choosing the subject matter that is to be taught to children. For the past ten years, scientists and teachers have been working cooperatively on this problem to produce new science materials for both elementary and secondary schools.

Let us look at an area commonly included in elementary science curricula—Living Things. The majority of pupils in elementary school study living things, but what are the pupils expected to learn? Past curricula taught generalizations such as, "There are many different kinds of animals," "Pets are our animal friends," "Earthworms help to make the soil good for the farmer," "The toad has a tough, dry skin," and "The toad uses its forked tongue to catch insect pests." The difficulty with such facts is that they do not *explain*; they do not help the pupil to grasp the underlying *structure* of the science of living things. Such facts about natural phenomena give descriptions in only a general and superficial way.

In contrast, the present trend in science teaching is to emphasize *key concepts* rather than specific facts. Specific facts are included, but they are seen in relationship to the key concepts. Granted that the toad has a tough, dry skin; the scientist then asks, "What does such a skin *do* for the toad?" In answering this question, the scientist draws upon the key concept of *adaptation*—adaptation being the adjustment that an organism can make to a given set of conditions because the organism possesses certain structures that have survival value and that are passed on to offspring. Such a concept explains many phenomena, from the dry skin of the toad to the claws of the lobster.

Next the scientist asks, "How does it work?" For example, "How is the forked tongue of the toad adapted to the particular diet of the toad?" "What enables the bat to hunt at night?" "How are the eyes of the bat adapted to night flying?" These questions lead to another key concept—the interdependence of structure and function. Again, as with adaptation, this key concept explains many phenomena: The tongue of the toad is uniquely built for "lightning-quick" action in catching and holding onto flying insects; the eyes of nocturnal animals have more rods than do

the eyes of other animals, and so the nocturnal animals are able to use the available light to see in very dark places.

The question of, "How does it work?" in relation to living things eventually brings the investigator to the cell, the basic unit of life. The key concept with which he works here is that the cell can be compared to a factory where raw materials are processed according to chemical instructions inherent in the genes of the cell. The cell's finished products are released into the bloodstream to find their way to the appropriate part of the organism.

From "How does it work?" the scientist goes on to ask, "How did it come about?" The answer to this last question lies in the evolutionary principle that individual differences in the offspring of an animal are passed on to succeeding generations if the differences have survival value. Over millions of years, these differences have led to the enormous diversity of living things in existence today. For example, pupils can trace from a common ancestor the gradual evolution of separate families of dogs and cats. Such an activity is more intellectually exciting than merely learning the fact that "The dog is man's friend."

In the physical sciences also we can find a contrast between the "old" science and the "new" science taught to elementary school children. Let us take, for example, the topic of motion. In many programs, a pupil learns, "A wagon goes faster downhill because of gravity; gravity pulls things toward the center of the earth." But to tell a pupil that gravity makes something accelerate on a decline is only to give a *name* for the phenomenon; it does not really *explain* the phenomenon. For an explanation of any motion, the scientist turns to Newton's three laws. The scientist can predict from one of them that a constant force applied in the direction of the motion will make the object accelerate. This key concept of the effect of a constant force can be used over and over again—to explain why a bicycle will accelerate even though the rider pedals with the same force or why an object falls faster as it nears the ground.

The scientist, using another of Newton's laws, can also predict that for any action in one direction there is an equal and opposite reaction. Again we find that this key concept can be used over and over. The frog is capable of a broad jump of several feet, but only by pushing backward against the mud or sand from which it springs. An inflated balloon released in the air will push forward rapidly as the air inside the balloon jets out, demonstrating the principle of movement of a jet airplane.

THE CONCEPTUAL FRAMEWORK OF "SCIENCE FOR TOMORROW'S WORLD"

From a study of what scientists themselves consider important in science, the authors of this series have identified key concepts to serve as the conceptual framework for an elementary science curriculum. It is interesting to note that these concepts are limited in number; in only ten statements, presented in the section that follows, we have been able to encompass the principal achievements of all of science. These key concepts are the backbone of the science curriculum developed in this series. Each of the concepts has been broken down into elements and the elements arranged from the simple to the more complex, so that the structure of a discipline is gradually acquired by pupils as they progress through the grades. Examples of such sequential development follow.

1 *Events in the natural environment happen in an orderly rather than a haphazard way; man searches for laws to explain this order by observing, hypothesizing, checking his ideas, and rejecting those which do not square with reality.*

Throughout his study of science in elementary school, the child ought to come to grips with the ques-

tion of what science is all about and how the scientist proceeds to carry out his work. To many children, science merely means such things as satellites going off into space, mysterious brews bubbling over Bunsen burners, or tiny forms of life being viewed under microscopes. The children identify conspicuous activities of some scientists as being science itself, erroneously viewing the purpose of the scientist as essentially practical—to make life easier, safer, and more livable for man.

How can we convey a different picture? How can we help the child to acquire a concept of science as a search for order in the universe? Even the young child is aware of events in the natural environment. He is aware of change—day changing into night, leaves falling and new leaves appearing, grass turning brown and then green again, weather changing, living things changing with age. But what the child is not aware of is that events happen in an orderly rather than in a haphazard, or chaotic, way. The child who first enters school is inclined to explain events by anthropomorphism, attributing to natural phenomena either a human knowledge or a human-like will to make things happen. Thus, grass turns green "because it wants to and because green is prettier," and birds fly south "because they know that winter is coming." The problem for the teacher is to encourage and help children to view science as an attempt to explain natural phenomena, not in terms of anthropomorphism, but in terms of certain fundamental natural laws.

There are several ways to accomplish this objective. The content of science itself helps. The primary school pupil studies tornadoes not as chaotic events but as the result of changes in air conditions. He finds out that a seesaw is balanced not because "the seesaw wants to," but because the *forces* on each side of the seesaw are balanced. Scientific explanations for familiar phenomena help the child appreciate science.

Emphasizing the key concepts that make up the structure of science is another way to help children to view science as a search for order in the universe. For example, the child who from the first grade has been exposed to basic concepts about the motion of objects tends to develop a conception of science as a search for basic laws. Such a conception is radically different from the conception of the child who continually interprets events in the world of nature in terms of their meaning for man only. A science curriculum that emphasizes such concepts as that some animals are useful to man conveys a very different idea of science from that conveyed by a curriculum that says that no two offspring of an animal are alike; differences passed on from generation to generation tend to accumulate, so that over millions of years a tremendous variety of living things has evolved on the earth ("Life on the Earth," Book 6).

Exposing a pupil to the "scientist's science" is one way of widening the child's appreciation of science. Another way is to include a historical perspective of science. In *Science for Tomorrow's World,* for example, as children find out how man's ideas of the solar system have changed over the centuries, the children come to view science as a questing for better answers. One "Pathfinders in Science" section in Book 3 illustrates how the genius of one man, Copernicus, caused an unwieldy concept of what is happening in the world of nature to be replaced by a more lawful concept—one that fitted the facts and explained the solar system more simply.

Still another way of conveying to pupils that science is a search for laws that explain events in the natural environment is to expose the children to the methods of science. Beginning with Book 3 of this series, and in each succeeding book, there is an introductory unit that conveys to pupils what the scientist tries to do and how he goes about his work. The child sees the importance of observation at every point. From observations of similar situations, he, like the scientist, tries to extract a kernel of knowledge, a principle that has wide application. The kernel is a

hypothesis only, for as the child comes to realize, a scientific principle is tentative; it may or may not explain new observations, and so ultimately it may have to be discarded for a point of view that can deal more successfully with the phenomena to be understood. Over and over again, the pupil finds out how man has changed his viewpoint on many things—the nature of changes on the surface of the earth (Book 3), the movement of the planets in the solar system (Books 3 and 6), what light really is (Books 4 and 6), what all matter consists of (Books 4, 5, and 6), and how magnetism and electricity are related (Book 6).

2 *Lawful change is characteristic of events in the natural environment; although living things tend to produce living things like themselves, over millions of years the earth and living things on the earth have changed, and diversified forms of life have evolved.*

As we have pointed out, even the young child is conscious of changes in the natural environment, but he lacks, as did man for thousands of years, the historical perspective. The young child does not realize the cumulative effect of the small changes that he sees going on about him. Waters may muddy as they tear away at the banks of a brook or a creek, but the child does not see that a Grand Canyon is ultimately produced by such forces. He hears of a new breed of insect that is immune to DDT, but he does not see the same principle at work producing the tremendous variety of living things in existence today.

In this series, throughout each of the books, the child is exposed to the concept of orderly change. This concept of orderly change over an extended period of time begins in Book 2 with the account of the life cycle of the moth. In Book 3, the pupil is introduced to the notion of changes in living things and in the surface of the earth, while in later grades these changes are spelled out in considerably more detail. For example, in the unit entitled "How Animals Behave" (Book 6), the reader finds out how two separate families, dogs and cats, evolved gradually from a common ancestor.

3 *To find order in the natural environment, the scientist seeks basic units that can be put together in an almost infinite variety of ways; the cell and the atom are examples of such units.*

We begin the development of this concept by helping the young pupil to discover the fact that, like all other substances, air takes up space. In fact, the door of an "empty" car may be hard to close because of the pressure of air inside the car. The child can find out more about the "stuff" of which air is made by warming the air in a closed glass container and watching the beads of water collect on the cover. From such experiences he discovers that matter can exist in particles that are too small to be seen with the naked eye—particles such as the individual molecules of water in a cloud of water vapor or the individual cells that make up the pupil's body. Beginning in grade 4, he can use a magnifying glass to make some very small things visible and to examine actual cells or pictures of cells with a microscope. His knowledge of the structure of the cell is expanded, bit by bit, and the bits are related more fully in a separate unit on cells in Book 5. Similarly, readiness for the study of the atom is built throughout the grades, culminating in the chemistry unit in Book 5.

4 *All objects in the universe and all particles of matter are constantly in motion; man has discovered and stated the laws governing their motion.*

The study of the basic science of motion begins in Book 1. Here the pupil learns that things do not start to move by themselves: A push or pull, called a *force*, is necessary to make a thing move. As the pupil advances to Book 6, page 106, he will learn the formal

name for the principle introduced here—the principle of inertia—but for the first grade, the concept is developed without use of a formal name. The second grade pupil learns more about the laws of motion: Once an object is moving, it continues to move in the same direction and at the same speed, unless another force acts upon it; for example, a passenger in a car continues to move forward when the car stops suddenly, unless a force in the opposite direction is applied by an opposing object, such as a seat belt. In Book 2, he also discovers that a steady force on an object in motion will make the object speed up. In Book 5, the pupil delves into the discoveries of Newton and learns that an object shot off into space has two kinds of force acting on it—a forward force, causing the object to continue in the same path and at the same speed at which it started (a review of the concept taught in Book 2), and a downward force, resulting from the force of gravity (a review of a concept taught in Book 3). The effect of these two kinds of force working on the object is that the object follows a curved path, since the constant forward force of the object is continually being deflected by the constant force of gravity.

The motions of heavenly bodies and the laws governing those motions are also presented in step-by-step fashion. The primary grade pupil finds out how movements of the earth in relation to the sun cause daily and seasonal changes, while the intermediate grade child studies the differing theories of Ptolemy and Copernicus to better understand the motions in the solar system. The movement of stars as a navigational aid is explained in Book 8, and the meaning and use of time zones is included in Book 9.

Not only are the motions of the largest objects in the universe covered by this key concept, but so also are the motions of the smallest particles. In grade 4, the pupil is first introduced to the concept of molecules and their motion in moving air. The grade 5 pupil learns that the state of matter—solid, liquid, or gas—is determined by the motion of molecules, and the grade 6 pupil finds out about the rotations of electrons within the atom.

The study of motion is not confined to the physical sciences. As the pupil studies the circulation of blood (Books 3 and 5), the transportation systems of plants (Books 4 and 6), and the movement of materials in and out of cells (Books 3, 4, 5, and 6), he has the opportunity to apply physical principles (such as the concept of diffusion) to the functioning of living organisms.

5 *The motion of particles helps to explain such phenomena as heat, light, electricity, magnetism, and chemical change.*

To the elementary school pupil, it may seem unreal that the particles of matter in all objects are constantly in motion. It may be hard for him to think of his desk, for example, as being made up of moving particles. In his desk, as in any solid, the average position of the particles is fixed; they cannot move past one another, although they can vibrate. But if the pupil rubs his fist hard and fast over the surface of the desk, the spot warms up as the particles move more rapidly and farther apart. He can infer from certain experiences—the transfer of heat from warm things to cold things, the expansion of hot objects and the contraction of cold objects, the heating up of a wire carrying an electric current, the growing of a crystal in solution, the process of chemical change—that particles *do* exist and that they must be in motion to produce the phenomena he is observing. In fact, it is *only* as the pupil becomes aware of the motion of molecules that he can understand such phenomena as heat, light, electricity, magnetism, and chemical change.

Readiness for the concept of molecular activity begins in the primary grades. In Book 1, the child discovers that there is a relationship between temperature and rate of evaporation. In Book 2, the effect of heat upon volume of gases and liquids is introduced,

as is the relationship of heat to changes in state of matter from solid to liquid to gas. In Book 4, the pupil finds out about electron motion in current electricity, and in Books 5 and 6, he learns about the structure of the atom and the concept of the motion of particles applied explicitly to heat, light, electricity, magnetism, and chemical change.

6 *There is a basic tendency toward stability or equilibrium in the universe; thus, energy and matter may be transformed, but the sum total of matter and energy is conserved.*

Beginning with Book 2, pupils get their first exposure to one of the key concepts of science—conservation of matter. At this level, pupils discover that the matter (a ball of cookie dough) remains the same even though the matter may be transformed in appearance (made into cookies). In grade 3, in connection with a study of changes on the earth, pupils find out that while a river may cut deeper and deeper into its bed, carrying away soil in the process, the soil that is carried away does not dissolve into nothingness in the water. The soil may be transported and dropped at the river's mouth, but it is not lost. *The total amount of matter in the system at any point in the transformation remains the same.*

Similarly, the pupil learns that energy can be transformed. The primary child can understand that energy in the form of gasoline in the tank of a car must be transformed by burning if the car is to be able to move. In the same way, energy is produced in the body when food is burned during the digestive process. Furthermore, there is a relationship between the amount of energy available to do work and the intake of fuel or food. A car without gas will stop, and a hungry person soon becomes tired. Such commonplace, easily understood examples provide the basis for understanding the concept that although man may make transformations in a system, the equation for the system will balance at the end of the transformation.

7 *When equilibrium is upset in organism-environment interactions, regulatory mechanisms go to work to restore equilibrium.*

This key concept involves the basic tendency of organisms to strive for equilibrium. Temperature regulation is one of the best-known examples. In human beings, equilibrium with respect to body temperature exists at about 98.6° F. Evaporation of water from any surface has a cooling effect. When the body becomes overheated, we perspire, and equilibrium is restored; when the body is chilled, goose bumps on the skin reduce the exposure of blood vessels to the cold, and body heat is conserved. When equilibrium in body temperature is restored, the goose bumps subside.

From the simplest plants and animals to the most complex, we can find illustrations of how certain mechanisms go to work to restore equilibrium when it has been upset. These mechanisms serve the function of helping the organism to survive.

8 *There is a relationship between structure and function; the structure of parts of living organisms determines the function of those parts.*

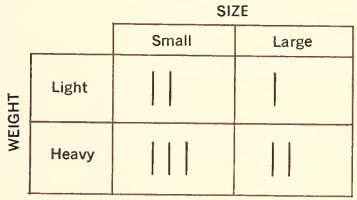
In the development of this key concept, we use the same approach as for the other key concepts in *Science for Tomorrow's World.* We begin in the primary grades with examples of the relationship between structure and function. Even the first grade pupil can observe in real life or in pictures that not all birds can scoop up fish from the sea or dig for insects in the trunk of a tree. Observations lead to the concept that the beak structure of a bird enables the bird to obtain food in a special way—a concept that leads to further observation and discovery of more specifics. For the older pupil, the relationship is stated explicitly. First

the pupil is exposed to many examples: in the unit on "How Animals Behave" (Book 6), there is a detailed discussion of the sensory receptors of animals—from the planarian to the fish. The remarkable chemical receptors of the male fish not only enable it to detect male-female differences in other fish of the same species, but also to detect when the female is ready to mate. Even the simple planarian, as pupils can observe, uses chemical receptors on each side of its head to detect food, waving the receptors from side to side to find the greatest source of stimulation. Thus, the key concept is stated for the pupils: "The way in which sensory receptors are made (their structure) is related to how they work." The pupils are then asked to apply the concept to any independent observations they make of animals not discussed in the text.

9 *The scientist has developed measures of space, time, and matter so that he can communicate explanations that are reproducible and make predictions about events in the natural environment.*

That there is a relationship between mathematics and science is common knowledge. The student, however, should be encouraged to deal with the relationship well before he has to use calculus in high school physics; as is true for other key concepts in the basic structure of science, readiness should begin in the primary grades.

The first step in a pupil's appreciation of the relationship between mathematics and science is to have him quantify his data. This can begin in the first grade. A pupil learns that a seesaw is in equilibrium when the same number of books of equal size and weight are placed equidistant on both sides of the fulcrum. Through experience, he learns to coordinate weight and distance in a systematic way; a large weight at a small distance on one side balances a small weight at a large distance on the other side. Quantification of data extends to record keeping, and *record keeping involving two variables is encouraged.* In Book 2, for example, pupils learn to keep a record of the temperatures of jars of water that have been covered with materials of different colors. The children also learn to record the length of time that the jars are kept in the sun. Thus, both temperature *and* time are recorded. The important mathematical concept of *function*—that a change in one variable can result from a change in another—receives reinforcement here. Record keeping in the form of a double-entry table is encouraged. Use of such tables need not be postponed until the upper grades; even a pupil in the second grade can learn to read a double-entry table, as well as to classify certain objects in terms of size and weight:



This chart, for example, shows that of the objects to be classified, two are small and light, one is large and light, three are small and heavy, and two are large and heavy.

Many experiences of this kind help the pupil to develop the mental agility needed to deal with concepts involving two variables. Thus, in *Science for Tomorrow's World, speed* is defined in terms of distance covered in a certain length of time; *density* is defined by the amount of matter contained in a given volume of space; *force* is defined by the relationship between mass and acceleration. The pupil who can see such concepts on a graph is clearly better equipped to deal with these concepts. He can think more understand-

ingly about them because his mind has been trained to think in this fashion during the period of his elementary school years.

Two units in particular in *Science for Tomorrow's World* are devoted to the relationship between mathematics and science. Book 5 contains a unit on "Testing Ideas," which introduces pupils to probability theory; an entire unit in Book 6 is devoted to developing the concepts of "a unit of measurement" and the "meaning and methods of measuring space, time, and matter."

10 *Man has changed and continues to change the natural environment; but because he is often ignorant of long-range consequences, his actions may have harmful effects for himself and for other living organisms.*

One of the basic problems facing modern man is that of maintaining a dynamic equilibrium with his environment. It is commonplace today to point out the rapid pace at which man is depleting elements of his environment. Water and air pollution, overpopulation, and improper use of chemicals are only a few of the many problems that man must solve if he is to function at an optimum level in the world of nature. Many such problems arise because man does not foresee the long-range consequences of his actions. For example, no one was able to predict that the wholesale use of DDT for the spraying of insects would result in the killing of many birds, or that the clam and oyster industries along parts of the Atlantic seaboard would be threatened by the dumping of wastes into coastal waters. Man must begin to develop foresight if he is to survive; he must become more concerned with the *total* natural environment.

There are moral and philosophical, as well as scientific, considerations involved in the above key concept about man and the natural environment, and obviously the elementary school child is not equipped to deal with them. But even a second grade pupil is capable of understanding that living things need air, water, food, and proper temperatures to survive. He can find out by experimentation what happens to plants deprived of one or more of these essentials of life. Third grade children can learn what is needed to make safe drinking water and, also, how man has contributed to water pollution. By the fifth and sixth grades, pupils are ready for a study in greater depth of some of the many other problems of man's own making ("Life on the Earth," Book 6). Of course, pupils cannot arrive at solutions to these problems, but the teacher can create a climate of opinion so that in later years, as adults, these same pupils will be more aware of both the necessity of managing natural resources with greater intelligence and the long and thorough pilot studies that are needed before any new products and solutions can receive full-scale application.

The ten key concepts that we have discussed form the structure of science in *The Macmillan Science Series*. Two things are worth emphasizing about these key concepts. The first is that all of the structure of science can be set forth in *so short a list;* the second is that there is considerable agreement among scientists that these ten key concepts actually *do structure science*. The reader may be interested in comparing the key concepts basic to *The Macmillan Science Series* with the set of propositions published by the National Science Teachers Association. These propositions are the result of extensive studies concerning the question of what to teach elementary school children. These studies were carried out by scientists and teachers working together. The following list, quoted from *Theory into Action,* published by the National Science Teachers Association, Washington, D.C., (1964) represents seven conceptual schemes and five major items in the process of science that were tentatively defined by the NSTA Committee as constituting the structure of science.

1. *All matter is composed of units called fundamental particles; under certain conditions, these particles can be transformed into energy, and vice versa.*

2. *Matter exists in the form of units which can be classified into hierarchies of organizational levels.*

3. *The behavior of matter in the universe can be described on a statistical basis.*

4. *Units of matter interact. All ordinary interactions are either electromagnetic, gravitational, or nuclear forces.*

5. *All interacting units of matter tend toward equilibrium states in which the energy content . . . is at a minimum and the energy distribution . . . is most random. In the process of attaining equilibrium, energy transformations or matter transformations or matter-energy transformations occur. Nevertheless, the sum of energy and matter in the universe remains constant.*

6. *One of the forms of energy is the motion of units of matter. Such motion is responsible for heat and temperature and for the states of matter: solid, liquid, and gas.*

7. *All matter exists in time and space, and, since interactions occur among its units, matter is subject in some degree to changes with time. Such changes may occur at various rates and in various patterns.*

The following are the five major items identified as essential to the process of science:

1. *Science proceeds on the assumption, based on centuries of experience, that the universe is not capricious.*

2. *Scientific knowledge is based on observations of samples of matter that are accessible to public investigation in contrast to purely private inspection.*

3. *Science proceeds in piecemeal manner, even though it also aims at achieving a systematic and comprehensive understanding of various sectors or aspects of nature.*

4. *Science is not, and will probably never be, a finished enterprise, and there remains very much more to be discovered about how things in the universe behave and how they are interrelated.*

5. *Measurement is an important feature of most branches of modern science because the formulation as well as the establishment of laws is facilitated through the development of quantitative distinctions.*

SEQUENCE IN THE SCIENCE CURRICULUM

The task of curriculum building in science includes a number of steps, the first of which is the identification of the key concepts that together add up to an understanding of the meaning of science. These key concepts have already been discussed. We have included in *Science for Tomorrow's World*, at the various grade levels, illustrations of these key concepts so that the children may see them materialized in learning situations. However, it is also essential that each key concept systematically be broken down into smaller pieces of relevant information. These smaller pieces must be arranged in sequential order from simple to the more complex, and the pieces must be assigned to proper grade levels.

A well-constructed development of concepts, taught in "spiral fashion" throughout the elementary school years (reinforcing every other year or two what has been learned earlier, and then advancing to a higher level of understanding) is essential for a meaningful understanding of science. The charts on the next two pages illustrate the sequence that has been developed in *Science for Tomorrow's World*.

1 Events in the natural environment happen in an orderly rather than a haphazard way; man searches for laws to explain this order by observing, hypothesizing, checking his ideas, and rejecting those which do not square with reality.

2 Lawful change is characteristic of events in the natural environment; although living things tend to produce living things like themselves, over millions of years the earth and living things on the earth have changed, and diversified forms of life have evolved.

3 To find order in the natural environment, the scientist seeks basic units that can be put together in an almost infinite variety of ways; the cell and the atom are examples of such units.

4 All objects in the universe and all particles of matter are constantly in motion; man has discovered and stated the laws governing their motion.

5 The motion of particles helps to explain such phenomena as heat, light, electricity, magnetism, and chemical change.

BOOKS IN WHICH KEY CONCEPTS ARE DEVELOPED AND THE NUMBER OF UNITS IN EACH BOOK DEALING WITH THE CONCEPT

KEY CONCEPTS	*BOOKS*						*TOTAL UNITS*
	1 (6)*	2 (6)	3 (6)	4 (9)	5 (9)	6 (9)	
1	6	6	6	9	9	9	45
2	1	3	1	1	1	2	9
3	0	1	1	2	3	5	12
4	1	3	1	1	3	3	12
5	3	3	0	1	2	3	12
6	2	3	1	5	4	3	18
7	1	3	1	1	2	2	10
8	3	2	1	2	3	2	13
9	1	2	0	2	4	7	16
10	0	0	1	0	1	1	3
Total Concepts	8	9	8	9	10	10	

** Number of units in the book*

6 There is a basic tendency toward stability or equilibrium in the universe; thus, energy and matter may be transformed, but the sum total of matter and energy is conserved.

7 When equilibrium is upset in organism-environment interactions, regulatory mechanisms go to work to restore equilibrium.

8 There is a relationship between structure and function; the structure of parts of living organisms determines the function of those parts.

9 The scientist has developed measures of space, time, and matter so that he can communicate explanations that are reproducible and make predictions about events in the natural environment.

10 Man has changed and continues to change the natural environment; but because he is often ignorant of long-range consequences, his actions may have harmful effects for himself and for other living organisms.

UNITS IN WHICH KEY CONCEPTS ARE INTRODUCED IN BOOK 4

KEY CONCEPTS	*UNITS*									*TOTAL UNITS*
	1	2	3	4	5	6	7	8	9	
1	X	X	X	X	X	X	X	X	X	9
2								X		1
3				X	X			X		3
4					X			X		2
5					X			X		2
6		X	X			X	X			4
7				X						1
8			X	X						2
9	X							X		2
10									X	1
Total Concepts	2	2	3	4	4	2	2	6	2	

TEACHING UNITS

Once major generalizations have been identified and the flow of ideas from grade to grade is roughed out, it then becomes necessary to plan teaching units suitable to the developmental level of the child. Each unit covers a period of instruction varying in length from two to four weeks. Such an arrangement of text material in eight or nine major blocks of subject matter permits more efficient teaching and learning than when a text is divided into thirty chapters with a different topic for each chapter. Under the unit arrangement the teacher does not shift gears every few days, having to gather equipment with each shift as well as having to reorient pupils' thinking.

The Table of Contents, which lists the titles of each unit of the first six books, is reproduced in Part IV. By looking at the titles, a teacher can tell at a glance whether or not the pupils have had any previous exposure to a particular area. The sequence charts on page 20 will reveal the amount and quality of the exposure.

An examination of the titles reveals some immediately familiar areas in science education. Such topics as "Probing the Atmosphere," "Living Things—Green Plants," "Light and Sight," and "Using Electricity" have been part of the elementary science curriculum for many years; although, as has already been pointed out, the specifics taught under each topic have often been different. In studying about light, for example, the children do not learn only that light is made up of particles traveling in a straight line; the children also learn that light particles travel in a wave motion, similar to the motion of a water wave when a pebble is dropped into a pond. Elements of key concepts are built into the topics, so that, although the topic itself is not new to the curriculum, each element becomes a vehicle for teaching the structure of science from a contemporary point of view.

Some topics reveal new developments in the sciences. Conservation of water resources and problems of air pollution are being emphasized today as much as conservation of soil was emphasized a few decades ago. This trend is reflected in the unit "Life on the Earth" (Book 6). Oceanography, for another example, is a rapidly expanding field of knowledge. With so many basic scientific data now known about life in the sea, ocean currents, salinity, and the geology of the ocean floor, the study of oceanography well deserves a place in the elementary science curriculum. The picture story "Probing the Oceans" (Book 5) highlights the work of oceanographers at the Woods Hole Oceanographic Institution, Woods Hole, Massachusetts, and will stimulate interest in this exciting field. Similarly, the stepped-up pace of man's exploration of space leads not only to the inclusion of space travel, but also to an increased emphasis on the science of astronomy.

PART II: HOW CHILDREN ACQUIRE SCIENCE KNOWLEDGE: A DEVELOPMENTAL APPROACH

For any discussion of how children acquire science knowledge, educators today lean heavily on the work of Jean Piaget, a Swiss psychologist who has been working with his collaborators in Geneva for over 40 years on the study of cognitive processes. Cognitive processes are those intellective processes by which knowledge is acquired. Piaget has developed a theory of how these processes begin in infancy and how they change as the child matures. His theory is a developmental one; characteristics of children's thinking are described in age-related stages. On the basis of Piaget's theory, we can predict the thought processes of children within a certain age range. There are, of course, individual differences in maturity of thinking; some children, because of heredity and experience, are more advanced than others; but, according to Piaget, the thinking of all children tends to go through the same stages and, on the average, when they are at the same age.

Piaget's description of developmental stages in children's thinking has generated a tremendous amount of research on both sides of the Atlantic. Many investigators have worked on the problem of whether or not his theory is a valid one. The conclusion to date is affirmative; the same stages characterize the thinking of Swiss, Norwegian, English, French, Canadian, and American children. In fact, when the tests developed by Piaget and his chief collaborator, Barbel Inhelder, are given to subjects in different countries, investigators report that translations show almost identical wording in children's answers. American cognitive psychologists, like Jerome Bruner of Harvard University, have extended and refined Piaget's theory, so that today we have a well-constructed and validated model of the thinking processes involved in the acquisition of knowledge. An understanding of how children acquire knowledge is basic to improvement of the teaching-learning process; we cannot help children to become better thinkers unless we know something about thinking processes and how they change with age, nor can we construct effective textbooks without taking into account developmental changes in cognition.

How can we put the findings of Piaget and other cognitive psychologists to work in teaching science? As we have pointed out, one of the aims of science educators is to teach the methods of science, to teach the child to use the same logical processes of thinking that a scientist uses to solve problems. For too long,

teaching the methods of science has meant teaching children to follow a formula: Observe; Hypothesize; Test; Evaluate. The formula is still valid, but it is not enough. The child in primary grades *does* observe, but, as we know from Piaget's work, he is likely to focus on the wrong property of an object or event as he observes. Similarly, the pupil in intermediate grades *does* hypothesize, but if he picks out the wrong variable for testing, he doesn't know what to do next. Nor does he know what to do next if he gets positive results from testing, for he doesn't know the specifics of "Evaluate"; he doesn't know, for example, that he must test for ex*clusion* of other variables.

In developing *Science for Tomorrow's World* we set as goals that the texts should not only help the child build a structure of science (the scientist's science), but should also develop logical thought processes. We believe that the study of science can help children become better thinkers, but that there must be deliberate planning to achieve this end; the improvement of thinking processes should not be left to chance. Guided by the discoveries of Piaget and other cognitive psychologists, we have used content, activities, and illustrations in the series to foster logical thinking. We will now discuss what is known about the normal course of intellective development, before discussing how that knowledge can be put to use in teaching science.

For Piaget the development of intelligence begins as early as the cradle stage and continues through stages from birth to maturity. The first stage Piaget calls the sensorimotor. The infant comes into the world with two kinds of reflexes: those, such as the knee-jerk, that are not altered by experience, and others, such as grasping and sucking, that are modified as the infant exercises them. The modification occurs through assimilation and accommodation. The infant, for example, accommodates the grasping reflex to the shape of the object to be grasped, curving his fingers one way to grasp a long narrow object, and in a different way to grasp a ring. During the first 18 months, the infant carries on countless transactions involving space, time, matter, and causality which build and reshape developing mental structures. Witness what happens with respect to the notion of permanence of object. To the 2-month-old infant, the game of peek-a-boo is meaningless; for him an object ceases to exist when it disappears from view, and out-of-sight is out-of-mind. Later in the first year of life, the infant knows that an object continues to exist and delights in searching for it when it is hidden. He "knows," not in words, but in his sensorimotor system, in much the same way that we may "know" how to find our way through a still strange building the second time. For Piaget, sensorimotor intelligence is the intelligence of action. The infant must first carry out displacements in his a*ctions,* rather than in thought. If an object is hidden first in one place and then another while the toddler looks on, he must carry on a physical search for that object, going from cushion to cushion; he cannot sit back and point triumphantly to where the object is, for he cannot visualize its displacement in his mind. However, by 18 months the child is capable of representation, of imagining the environment other than as he directly perceives it.

The next stage, the *preoperational,* extends from 18 months, roughly, to about 7 years. It is in this stage that we find most first and second grade children—and, of course, some children even older than 7 years. This stage is called "preoperational" because the child does not use logical operations in his thinking. We can summarize the characteristics of pupils' thinking at this level as follows:

1. *The child is perceptually oriented; he makes judgments in terms of how things look to him.* When given a problem in which two lines of ten segmented sticks of equal length are laid out in parallel rows, he will see that both lines are equal. He will see that two dolls, walking along these paths, would each walk the

same total distance. But if one of the rows is rearranged in a zig-zag fashion, when the child is again asked if each doll takes as long a walk as the other, the child says, "No." Even when he counts the segments, he denies equality; the child does not see that there is a logical necessity in which ten must equal ten. Piaget has shown that this same type of perceptual judgment enters into the preoperational child's thinking about space, time, number, and causality. It is only as the child goes beyond his perceptions to perform displacements upon the data in his mind (for example, visualizing the second row of sticks straightened out again) that conservation appears.

2. *The child centers on one variable only, usually the variable that stands out visually; he lacks the ability to coordinate variables.* For example, a kindergarten child is pouring juice into paper cups. The standard-size cups run out, and the teacher substitutes some that are much higher but are also smaller in diameter. As the children drink their juice, several comment on the fact that Jimmy, Eddie, and Danny have more juice. Why? Because those children have cups that are taller. The dimension of height, not width, stands out. The child's thinking is rigid; he does not perform operations on what he sees. Later he will reason that "higher than" is compensated for by "skinnier than," and that both kinds of cups may hold the same amount of juice. This ability to see reciprocal changes in two sets of data is an important logical tool available to older children but not to the preoperational child.

3. *The child has difficulty in realizing that an object can possess more than one property, and that multiple classifications are possible.* It is hard for the child to see that one can live in Los Angeles and in California at the same time, that a bird is also an animal, and that, since there are animals other than birds, there are logically *more* animals in the world than there are birds. The operation of combining elements to form a whole and then seeing a part in relation to the whole has not as yet developed, and so hierarchical relationships cannot be mastered.

So far, this consideration of preoperational thinking has been largely negative. We have seen that the child lacks the ability to combine parts into a whole, to put parts together in different ways, and to reverse processes. What, then, can the child do? The development of logical processes is not at a standstill during this period; there are some positive accomplishments. We see, for example, the rudiments of classification: the child can make collections of things on the basis of some criterion; he can also shift that criterion. Thus if we present a kindergarten child with a collection of pink and blue squares and circles, some large and some small, and ask him to sort them into two piles with those in each pile being alike in some way, he can usually make two different collections on the bases of color and shape (a few children discover the third criterion of size). Such an ability, of course, is essential to the formation of classes and eventually of a hierarchy of classes.

The child is also beginning to arrange things in a series. He can compare two members of a set when they are in a consecutive order; he knows that Tuesday comes after Monday. But since Friday comes after Tuesday, which is after Monday, does Friday also come after Monday? This operation, involving seeing logical relations between things or events that are arranged in a series, is not yet possible to the preoperational child, but experiences with seriation are preparatory to the development of such operations. The "inching up" that an older pupil does in trying to establish equilibrium between two parts of a physical system (add a little to one side; then add a little to the other) is an example of a more sophisticated use of seriation.

Between 7 and 11 years of age on the average,

as the child assimilates information from his actions and accommodates mental structures to the new information, thinking processes change. The child abandons his perceptual judgments and thought takes on certain logical properties. Piaget calls this stage the stage of *concrete operations,* because, while the child uses logical operations, the content of his thinking is concrete rather than abstract. One of the mental operations that develops is that of combining elements; the child begins to put two and two together figuratively as well as literally. He uses this combining operation to discover (though not until toward the end of this stage) that a substance like sugar added to water will make the water level rise, and that the water level will stay up even after the sugar dissolves. It dawns on the pupil that matter combined with matter produces more matter, that matter doesn't disappear into nothingness.

Another property of logical thought is that elements of a whole can be associated in various ways without changing the total. Thus, in the problem of the segmented sticks, the segments can be "associated" in a straight line or zig-zag line, but the total distance of the path to be covered remains the same, or is conserved. And in studying science, the pupil can use the associative operation to discover how to keep a system in equilibrium—how, for example, when a muscle is flexed, it becomes shorter but thicker; when relaxed, it is longer but thinner. In each case, the total amount of muscle remains the same; the amount of matter is conserved, though its shape is changed.

A third property of logical thought is that of identity. The identity operation is basically a null operation; the child can mentally cancel out the effects of any operation by combining it with its opposite. He uses such an identity operation to reason that the effects of adding a force to one side of a balanced tug-of-war can be canceled out by adding a force to the other side (at the preoperational stage, he could solve the problem only by taking away the extra force that had been added). The pupil can also reason, as he thinks about a flexed muscle, that, since nothing has been added to the muscle and nothing has been taken away, then quantity of matter is identical before and after the flexing. An extension of the identity operation is the one-to-one correspondence a pupil carries on to establish identity between two sets. Is the spider an insect? The pupil must compare each characteristic in the set of insect characteristics with each in the spider set, on a one-to-one basis, to answer the question.

Of all of the properties of logical thinking, one of the most critical to develop is that of reversibility. Every change that the mind makes upon sensory data is reversible. The child can mentally rearrange the sticks in the zig-zag line, putting them back the way they were, to see that length is conserved. Similarly, a pupil can solve the problem of whether matter in a total system is conserved when a river carries away soil and deposits it in the river delta by reversing the depositing process. (See Book 3, Unit 3.)

A good deal of the research of Piaget and Inhelder on how children think about problems has centered on conservation problems in which matter, weight, or volume is conserved with a change in form. Results show that children achieve conservation during the stage of concrete operations, but that some conservation problems are easier than others. Conservation of length (the segmented sticks) appears first, followed in turn by conservation of matter (pouring sand into containers of different shapes) and conservation of weight. Conservation of volume (dissolution of sugar in water) is most difficult, appearing at about 11 years.

The operations described above characterize the thought processes of the child during the elementary school years, but beginning at about 12 years, there are further changes that occur in modes of thinking. Thinking is less tied to the concrete and becomes more abstract and formal. Piaget describes it as *proposi-*

tional thinking. The pupil can state propositions in terms of the variables he has identified and can then systematically combine the propositions so as to test all possible combinations. To reveal thinking processes, a pupil is presented in one of Piaget's tests with four flasks containing colorless, odorless liquids that look exactly the same, plus a bottle containing potassium iodide (not identified for him). He is shown that a few drops from the bottle can turn the proper (but unknown to him) mixture of liquids yellow, and he is asked to reproduce the process. If the pupil is at the formal stage of thought, his statements will reveal certain characteristics of thinking not found in younger children. For example, he will say, "If this stuff in the bottle is plain water, then when I put it with a mixture from the first and second flasks, it shouldn't make them turn yellow." In effect he is stating a hypothesis for testing, "If it's water, it wouldn't do this," or that one statement logically implies another. At the concrete stage, the pupil says, "I'll put this and this together and see what happens."

There are four ways in which propositions can be combined. We can combine by conjunction, as when we say, "It's got to be this *and* this"; by disjunction: "It's got to be this or this"; by negation: "It's neither this nor this"; and by implication: "If it's this, then this will be true." Let's suppose, for example, that a sixth grade child is interested in the problem of what attracts certain insects to flowers; two possibilities are design and color. How to combine the two? At the formal stage of thinking, the learner can systematically test all the possibilities by asking:

Is it color and not design?

If it's not color, then is it design?

Is it design and color?

Is it neither?

Each of these questions must next be stated as a hypothesis for testing. The question, "Is it color and not design?" must be restated as the hypothesis, "If it's color and not design, then when we present both stimuli (which are specified) to the insect, we ought to attract more insects to the color." But following the checking out of that hypothesis, if color "works," the pupil must then ask, "If it's color, is it any color? Does yellow work as well as red? Do fluorescent colors work better than nonfluorescent? If color red is equal to color yellow, the number of insects attracted to the stimuli should be the same." The outstanding characteristic of thought at the formal stage is the way in which the mind can combine propositions, going back and forth with lightning-like speed, and then stating what the combination implies in the way of experimental outcome. This mode of thinking begins to appear in bright children even before they leave elementary school.

BUILDING A SCIENCE SERIES TO FOSTER LOGICAL THINKING

The developmental picture we have described has implications for building a science series to foster logical thinking, as we shall see. However, it should be pointed out here that cognitive psychologists have made contributions other than the developmental picture. Piaget and Inhelder have given us insight into the misconceptions about science that children acquire, so that we can plan remedial activities. Bruner has described the process of concept building, a process that begins with a sensorimotor experience, proceeds to a step where a mental image is important, and then is completed at the symbolic level, where verbal understanding is accomplished. Aspects of cognitive theory other than the developmental picture have been considered in building our science series.

Implications of Cognitive Theory for Content Selection and Grade Placement

In building a science series, there must be a rationale for the selection and grade placement of sub-

ject matter. Part of the rationale is derived from scientists' analysis of what is important in science; we have selected for the content in this series the "scientist's science," ordered in terms of difficulty of concepts. Part of the rationale is derived, also, from what we know about the child. If the study of science is to improve thinking processes as the pupil acquires content, strategy for improvement must be based on what is known of the normal course of intellective development. In our discussion thus far, we have described the *normal course*, not the potential; it is with the norm that we start to accelerate development, for American educators are rarely interested in maintaining the status quo in achievement levels. Knowing the characteristics of preoperational thought, we selected content for the primary books in this series that will help the child overcome preoperational deficiencies and facilitate development of those properties of logical thought that appear in the stage of concrete operations. Knowing how the child thinks at the stage of concrete operations, we selected content for the middle grades to strengthen logical operations and advance the onset of propositional thinking. As previously stated, we take the position in this series that the development of the highest mental processes should not be left to chance; the school should foster logical thinking in every way possible, and the study of science offers unique opportunities to do this.

Some examples at this point may help to clarify our strategy. Particularly in the first two books, we present learning situations to help the child overcome his tendency to make perceptual judgments and to center on one variable. In Book 1, for example, the pupil is helped to discover that *both* weight at each end *and* distance from the fulcrum must be considered in balancing the seesaw; centering on the weight variable is not enough. In Book 2, the young reader has experiences in co*ordinating* two variables; as he pours sand into containers of different shapes, he learns that "higher than" is compensated for by "skinnier than," so that quantity of matter is conserved. He is also given practice in identifying more than one property in classification problems; he discovers that sounds vary in *both* volume and pitch, and he works out with the teacher a 2 x 2 table (see page 4) to visualize the classification of the sounds to which he is listening.

But what of pupils in the first two grades whose thinking has advanced beyond the preoperational level? For such pupils, logical operations should be made explicit by the teacher so that their use, which may be only intuitive at first, will be strengthened. And the teacher, knowing the logical operations that appear in the average child 7 years old, can make every effort in all of her teaching to strengthen such thinking processes as they appear in pupils in the first two grades.

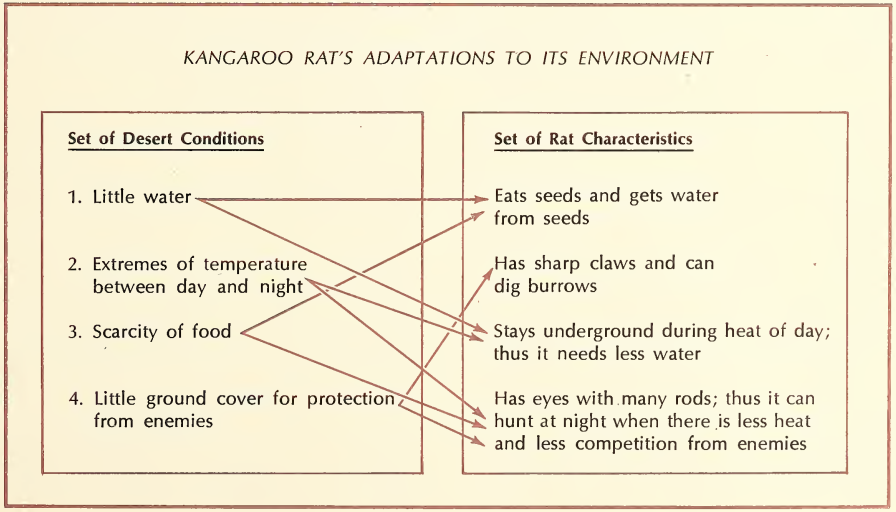
In Books 3, 4, and 5 there is increased emphasis on developing in the pupil these logical operations—combining elements, associating elements in different ways, establishing identity between elements, and reversing an operation—that characterize the stage of concrete operations (normally 7–11 years). There is considerable work, particularly in Books 3 and 4, on classification skills. Such skills began in Book 2, when a pupil learned to describe a specimen by more than one characteristic and then, to identify the specimen as either a butterfly or moth, to make a one-to-one correspondence between the characteristics of the specimen and those of the butterfly or moth. In Book 4, Unit 4, skills become more complex as the pupil learns about hierarchical classification. Fishes, amphibians, reptiles, birds, and mammals can be combined to form a superclass of "animals with backbones." Furthermore, certain things are logically true of the superclass and the subclasses (e.g., each member of the subclass must contain those characteristics that distinguish the superclass plus some others; a subclass is always smaller in number than the superclass.

Logical thinking is also demanded of the child in questions in the text or in the teaching suggestions.

Note the logical processes involved as a third grader attempts to answer the teacher's, "Can you give me an example of an animal that lives on the desert and explain how the animal can live in such an environment?" The pupil has read the unit "How Animals Live," Book 3, Unit 4, from which he learned about many animals adapted to many different environments. To answer the question, he must first combine elements that make up a set of desert conditions: little water, extremes of temperature, scarcity of food, little ground cover. He remembers the kangaroo rat as living on the desert, and combines elements that make up a set of rat characteristics: eats seeds and gets water from seeds, has sharp claws and can dig burrows, stays underground during heat of day and so needs less water, has eyes with many rods and so can hunt in the cool of the night. Then the pupil must set up a correspondence between elements in the desert-conditions set and elements in the rat set. If for the elements in the first set there are corresponding members in the other set, establishing an identity, then he knows the animal is adapted to desert living.

Logical operations continue to be emphasized in Grades 5 and 6, but in increasingly more complex situations. We can find many examples of operations particularly in the physical science content in Books 5 and 6. The development of the speed-time-distance relationship in Book 6 is a case in point. Note that the pupil must now see one variable as a function of two others and work out relationships among the three by using not one but several logical operations (reversibility, for example: if $s \times t = d$, then $s = d/t$; identity, as he puts in the correct numbers for the letter symbols).

Beginning in Book 5 and increasingly in Book 6, content encourages the pupil to do propositional


KANGAROO RAT'S ADAPTATIONS TO ITS ENVIRONMENT
Set of Desert Conditions
1. Little water
2. Extremes of temperature between day and night
3. Scarcity of food
4. Little ground cover for protection from enemies
Set of Rat Characteristics
Eats seeds and gets water from seeds
Has sharp claws and can dig burrows
Stays underground during heat of day; thus it needs less water
Has eyes with many rods; thus it can hunt at night when there is less heat and less competition from enemies

thinking. For example, in the introductory unit to Book 5, the reader is introduced to the specifics of scientific methods. He has, of course, been raising questions and doing "experiments" in the first three grades; he has even had practice in controlling certain factors while he experimented with another. In Book 2, for example, in the unit on heat, pupils experiment on the insulating qualities of different kinds of cloth. The size of the cloth and the temperature of the water to be protected are kept constant. But the question, "Does the color of clothes make a difference (in keeping us cool)?" is not stated as a hypothesis for testing. It implies a concrete operation, but it does not spell out the specifics for testing. It does, however, provide readiness for the fifth grader's encountering, in Unit 8, Book 5, the experiment, "How Do Dark and Light Colors Affect the Absorption of Heat Energy?"

There is one last point to consider in using the content of *Science for Tomorrow's World* to improve thinking processes. As Piaget has shown, the child deals less with the concrete and more with the abstract and the formal as thinking processes mature. We recognize this developmental change and have taken it into account in our planning to facilitate the appearance of abstract thinking, but we do not emphasize the formal expression of generalizations prematurely. There are many opportunities in the primary grades for pupils to deal with functions in a concrete way. In Book 2, for example, page 138, the pupil carries out an activity in which he discovers that the loss of heat over time is a function of the insulating properties of the protective material. This discovery as stated, however, is beyond the comprehension of most second grade children. Instead, the child of 7 summarizes in a concrete fashion: "With a wrapping made of wool, water doesn't cool off as fast as with wrappings made of cotton or rayon." In keeping with developmental theory, we reserve the more formal and abstract expressions of generalizations for Book 5 and Book 6.

Implications of Cognitive Theory for Activities and Illustrations

Cognitive theory is useful not only in planning content and grade placement, but also in planning learning activities and experiments and in designing special illustrations for tests. The reader will recall that in Piaget's theory, the first stage is the sensorimotor, where the infant may be said to "think with his muscles." While language changes the mode of thinking, the need for a motor component as an underpinning for certain concepts does not disappear with the advent of speech. Bruner in particular has noted the importance of motor activity as a first step in concept building. In this series we have recognized the importance of sensorimotor experience in planning learning activities. No verbal description of how gears work can substitute for the actual manipulation of gears (See Book 2, p. 52). No verbal description can convince the child that the image formed in the retina of what he is seeing is an upside-down image, but let him try building a pinhole camera (Book 6, Unit 6), and he has built into his sensorimotor system a basic understanding of the concept.

Activities with a motor component are not new to science, but what is new is that we now have a rationale for which concepts need this kind of sensorimotor underpinning. Concepts from the physical sciences, where two different displacements occur at the same time, need a motor component. The activities in Books 2, 3, and 6 in the units dealing with concepts of forces and motion contain many examples of such displacements. Sensorimotor activities are often needed, also, to correct misconceptions children have built up. Cognitive theorists have provided us with information about which concepts children are likely to be confused about. In the process of living and adjusting to his environment, the child has been dealing with such phenomena as time, matter, space, light, heat, motion, and electricity, and has more likely than

not built up misconceptions around them. Most children, for example, think that a steady push on an object results in a steady speed. The sensorimotor experience of feeling acceleration in the wagon one pushes with a steady push (Book 2, p. 39) *really* convinces the child in a way that telling him does not. Similarly, most children find it hard to believe that a ball flicked off from a table top and one dropped over the side at the same time will both reach the ground at the same time (Book 6, Unit 3). Understanding that a missile has both a horizontal and a vertical component of motion begins with a sensorimotor experience. (Book 5, Unit 8). And the future student of high school chemistry who has spent time in elementary school constructing models of atoms (Book 5, Unit 6) will find that the theory of chemical bonding comes naturally to him; he can imagine a model of the oxygen atom from his experiences.

Note that each of the activities mentioned helps to correct a misconception or to build a mental image of how something in the physical world *works*. Too much science-teaching time has been wasted in the past on activities with no foundation in an important science concept. Simply building a space station with model rockets in the classroom cannot be justified in terms of its cognitive value. While the activity has motor components, it probably generates more misconceptions than it clears up and contributes nothing to an understanding of the physics of space travel.

Following the sensorimotor experience (or assuming one in some cases), Bruner describes an *iconic* step in concept-building. After "meaning in the muscles," the child must build a mental image of what it is he is acquiring knowledge about. In this series we have aided the development of this step in the type of illustration used in special cases. The first grade pupil is introduced to the concept of a system in equilibrium through a sensorimotor experience with the seesaw. Then *diagrams* of the system are presented, with distance and weight clearly indicated as the variables. The diagram serves the function of giving the child a mental image of the essentials in the system. It is a pared-down version of the illustration showing actual children seesawing. In Book 2, force diagrams are used, again after a sensorimotor experience, to show both size and direction of the force in question. In Book 6, physical experience involved in understanding time-distance relationships is provided in graph making, the end-product of which then serves the image-building function. In Book 6, Unit 1, also, the learner becomes acquainted with vectors and builds a mental image of velocity with vectors.

With the proper sensorimotor and mental-image underpinning, the learner can then go on to deal with a concept symbolically—that is, with language. Like adults, the pupil who has difficulty in understanding the sentence, "The intensity of light varies inversely with the square of the distance from the source," falls back on sensorimotor memories. If he has actually worked out activities involving the inverse-square law, then he has some "feel" for what the term means. If, in addition, he can also bring to mind a mental image of a diagram of the inverse-square law applied to light, then the sentence takes on additional meaning.

Motor activities, mental images, language—all three steps are not necessary for all concepts. For some concepts, pupils bring with them to school a strong sensorimotor, mental-image foundation, and are ready for the symbolic step. But for other concepts, where the foundation has been missing or faulty, one or both steps are essential. With many concepts, as Piaget points out, knowledge is deformed by a purely verbal approach. Teachers are being advised today, in science teaching, as in all teaching, to spend more time to teach what used to be covered in a few minutes with a few verbal statements. The advice is good—provided the teacher picks the right concepts to concentrate on, and provided the extra time is spent wisely on those steps that build readiness for the verbal stage.

PROBLEMS OF MOTIVATION

Psychologists are generally agreed that motivation is the first essential to learning. If pupils are to learn science, they must first *want* to learn; they must be motivated. However, there are a number of misconceptions with respect to how a state of motivation can be induced. Some teachers confuse motivation with external stimulation supplied to interest children in a lesson. Thus one teacher says, "But I have no trouble in getting my children motivated. I just produce a few pieces of equipment and tell the class we are going to have an experiment, and they are all interested."

Readers will agree with the teacher that children are immediately attentive when an experiment is proposed, but teachers will also recognize that interest in observing an experiment does not necessarily lead to motivation to learn important science concepts. The behavior of children who receive chemistry sets for a holiday present is a case in point. Many a child delights in mixing the chemicals and watching the resultant change in color or state of matter, but for too many it is the magical "result" that intrigues, rather than the chemistry of the change.

For the psychologist, however, motivation is intrinsic to the organism. It is no secret that even the very young infant learns spontaneously and enjoys the process. Furthermore, he is motivated to learn even when there is no adult present to supply initial stimulation. A ten-month-old baby who wants a toy that is out of reach on a cushion in his crib discovers that by pulling on the cushion he can bring the toy within grasp. He is learning that one can use tools (the cushion) to extend the arm to reach objects in space. The motivation for the learning came from within.

Teachers, too, can give many examples of intrinsic motivation. In Book 6, in the unit entitled "The Nature of Light," an activity is described involving use of a homemade ripple tank to study the behavior of light waves. Sixth grade children with access to this equipment have been observed before school and in free time, placing obstacles across the tank or inserting sharp-edged rulers below the surface of the water, to see what happens to the waves they create with a dowel stick. Fourth grade children studying electricity hurry to the science table when assignments are finished, to experiment by winding wire around a nail for so many turns to find out the effect upon the strength of an electromagnet. There appears to be a basic urge to explore, to find out how the environment

can be changed, and to learn what consequences flow from these changes. When this motivation to interact with the environment is present, the child carries on activities with considerable persistence, getting interesting feedback from his efforts and acquiring knowledge in the process. In the language of Piaget, the child assimilates and accommodates, restoring mental equilibrium when accommodation has been achieved.

It is not difficult to find examples of self-motivation in pupil behavior. The problem for the teacher, however, is to set the stage so as to produce this kind of behavior. More specifically, it is the problem of how to induce intrinsic motivation so that the pupil learns what the teacher wants him to learn.

Let us consider the case of a fourth grade teacher who is about to teach a unit on sound. Among the concepts that she wants pupils to acquire are: (1) In order for sound to be produced, something must vibrate; (2) For human beings to hear a sound, vibrations must occur between sixteen times and twenty thousand times a second; (3) The kind of sound one hears depends on the number of vibrations. We know that pupils will acquire these concepts through a self-regulatory process, but what can the teacher do, what stimulation can she furnish, to get the process started?

Theorists of learning have identified the elements that make a situation stimulating and that induce intrinsic motivation. One such element is that of novelty. A relatively less familiar situation is more stimulating than the familiar, and human beings (lower animals, too) clearly prefer the novel to the well known. The situation, however, must not be too novel, for too much uncertainty breeds fear and withdrawal.

Some theorists prefer to call the stimulating element "cognitive dissonance." By that they mean that there must be a discrepancy between information already stored in the brain and information coming in from an ongoing experience. When incongruity exists, there is a basic urge to resolve it so that mental equilibrium is restored. A pupil may presently believe that the way to make a stronger electromagnet is to make it bigger; bigness and strength are associated in his mind. Thus he would predict that a heavy spike will attract heavier objects than a slim nail. Faced with evidence that contradicts this belief, he then experiments with nails of various sizes and with various turns of the wire to find out what actually increases the strength of an electromagnet. He acts to get rid of the incongruity and to restore equilibrium.

The problem, then, for the teacher who would induce motivation in children is to provide encounters with objects or situations that will be incongruous with information children already have. To provide such encounters, the teacher must first know where children are in their thinking with respect to the concepts to be taught. If the teacher wants pupils to acquire the concepts we have listed for the unit on sound, then the teacher must first know what the pupils already believe about how sounds are produced and what the pupils believe about the reasons that sounds are different in pitch and intensity.

One way to find out what pupils already believe is to ask them. A teacher can start a lesson with questions based on the concepts to be taught. Thus, the teacher might begin with the question, "What makes a sound?" To such a question the teacher is likely to get an answer like, "There's a sound when we hit something." The teacher counters this response by asking, "Are all sounds made by hitting something? Who can give me an example of a sound that is made without something being hit?" Examples such as shuffling a shoe across the floor, rubbing the desk with the back of the fist, speaking, etc., are incongruous with the notion that something must be hit for sound to be produced, and pupils are motivated to find out what *is* the common element in all of the examples that produces sound. A discussion centered around questions designed to expose the incongruity between presently held beliefs and evidence to the contrary can induce motivation to resolve the discrepancy.

Even better than the purely verbal approach to motivation is one involving motor activity. From the motor activity, a pupil can take in information not only through the auditory sense, but through the visual and tactile senses as well. Instead of using discussion and relying upon words to elicit cognitive dissonance regarding how sound is produced, pupils can engage in such activities as vibrating a ruler over the edge of the desk, snapping a rubber band held between the teeth, or observing dry cereal moving up and down on a vibrating drum top. Such motor activities are better than the verbal because (1) they are more interesting; therefore, pupils will be more attentive; and (2) they permit more information to be assimilated (the actual information input is greater than when discussion alone is used). The advantage of the motor over the verbal is only true, however, if the motor activity can produce enough novel stimuli to be motivating. A motor activity from which the child can perceive only stimuli too elementary for his level of cognitive development is obviously a waste of time.

Throughout *The Macmillan Science Series,* many activities are introduced that are designed to induce pupil motivation. These activities take more class time than a verbal discussion, but teachers are urged to take the time for them. Only as the pupil becomes aware of the discrepancy between what he has believed and the actual evidence he is assimilating from an activity will he be motivated to acquire new knowledge. Assimilation is facilitated by activities that permit a multisensory approach rather than a purely auditory approach.

We can summarize the modern approach to motivation as follows:

1. The teacher must have clearly in mind the concepts the children are to acquire in connection with the study of a particular topic. These generalizations are listed for each unit in the Teachers' Guide.

2. The teacher uses discussion or, even better, a demonstration or individual pupil activity to stimulate pupil thinking about a particular concept.

3. The teacher asks questions or redirects pupils' observations in order to reveal any discrepancy between stored information and informational input.

4. The discrepancy is stated as a problem to be resolved in the course of the lesson.

PLANNING FOR INDIVIDUAL DIFFERENCES

As in teaching any other school subject, the classroom teacher must plan for individual differences in teaching science. And as is true in other school subjects, individual differences in reading ability create the biggest problem. A fourth grade class of 30 pupils may have a reading range that varies from second to sixth grade ability. How can the teacher accommodate such a range? Teaching pupils in separate groups as is commonly done in reading and arithmetic is not feasible; there is a limit to the number of separate lessons a single individual can teach in a day's time. Nor is grouping within the classroom desirable, except on a temporary basis, for subjects like science and social studies, if each grouping involves a separate body of subject matter. In these subjects there is a core of concepts that should be part of the curriculum for all pupils. All pupils in a particular grade ought to have the chance to acquire those concepts at the level of difficulty possible for them. Some fourth grade pupils may acquire simpler concepts about energy such as "Energy can be transformed from one form to another in order to get work done," while others may tackle more sophisticated concepts such as, "When energy is transformed, the total energy at the beginning and end of the transformation is the same." Managing such a range is quite possible for the teacher.

To provide for the slow readers, it is necessary to find books at their reading level treating the same unit that is being studied by the rest of the class. This is often possible to do in a subject like science, where many of the same topics are encountered in alternate years or every third year. Motion, for example, is studied in grades 2, 3, 5, and 6; weather is a topic in grades 1, 4, and 5; units on living things appear in grades 2, 3, 4, 5, and 6. Other examples of a spiral organization can be found by scanning the complete Table of Contents, which appears in Part IV. Many schools are operating on a flexible plan with regard to the use of texts, taking advantage of the spiral organization in order to meet individual differences. A sixth grade teacher, for example, who has pupils who are retarded in reading, borrows from the third or fourth grade for the particular unit being studied. She introduces the unit in exactly the same way to the entire class, but after pupils have completed their differentiated reading assignments, she introduces into the class discussion some questions aimed at the less sophisticated concepts covered in the easier book. This part of the discussion serves as a review for pupils who are more advanced in concept development. At the same time, the slow learners have the advantage of seeing the demonstrations and following the discussion of harder concepts, all of which serves as readiness for acquiring the concepts when they are encountered later on. As every teacher knows, it is often the *second* explanation that makes assimilation and accommodation possible.

But what does the teacher do in the case of units *not* covered in an easier book? One solution is to vary the reading assignment, requiring slow readers to read less material. Some teachers work with the slow readers as a group, having the material read silently in small sections and its meaning discussed at the end of each section. Under no condition should a pupil be given a book that is beyond his comprehension, unless special help is also provided. Nothing will stifle pupil interest in science more quickly than a teacher who requires the class to read books that are too difficult. As is true both in social studies and in science, the content lesson is also a reading lesson, and the same principles of reading that hold true when pupils are using readers are valid when pupils are reading science texts.

Of particular importance to slow readers are activities and experiments. Slow learners need even more in the way of sensorimotor experiences than do fast learners. The slow-learning third grade pupil can learn the concept of force only by actually setting objects in motion under varying conditions. There is a temptation because they read so slowly to have slow learners spend more time on reading and less on activities. Reading assignments, however, should be adjusted for these pupils so that they also have time to engage in experimentation.

In the past decade, much has been written about the gifted child and about the necessity of providing him with challenging situations. A great deal of effort has been expended in the direction of providing enrichment activities. Unfortunately, however, so-called enrichment activities too often involve only *busy work;* that is, the activity keeps the child *busy,* but at exactly the same cognitive level that he has covered so far. A bright child can be kept busy working on an animal chart on which he lists animals, names of the baby animals, and where the animals live, but at the same time the activity may offer nothing in the way of intellectual challenge. The gifted child needs enrichment in *depth,* rather than horizontal enrichment. He ought to have the chance to tackle intellectually challenging problems that will lead to the acquisition of concepts more sophisticated than those to which the rest of the class is exposed.

If we agree that the gifted child should have enrichment in depth, the next concern is how to provide it. Because the bright pupil is a good reader, some teachers are tempted to keep him busy with special

reports. He is the person assigned to look up topics in encyclopedias or other reference books; but such assignments are all too frequently carried out by copying lengthy excerpts from the source. Special reports need not, of course, be pedestrian or routine. A book such as *King Solomon's Ring*, by Konrad Lorenz, with its fascinating observations of animals, not only brings additional knowledge to the bright pupil in the fifth or sixth grade who reads it, but is likely also to inspire him to observe systematically his pet goldfish or dog, the birds in the backyard, the squirrels in the park, and other animals in his environment. But all science study cannot be carried on only through vicarious activities; directed observation and experimentation, to discover more advanced concepts or to apply acquired concepts to more difficult problems, should also be encouraged in the bright pupil.

Let us examine two different activities proposed in connection with the study of the unit entitled "How Animals Behave" (Book 6). One activity asks that the student find the answer to the question of whether differences between species or differences between breeds of the same species are greater. Pupils are instructed to carry on a series of observations on dogs and cats—recording the animals' approaches to food, their manner of eating, and their behavior after the food has been eaten. By selecting various breeds in each category, comparisons across breeds as well as across species can be made, and data can be gathered to answer the question. The activity serves as reinforcement for key ideas covered in the text; it is one that can be carried out even by slow learners who, hopefully, will become more aware of similarities and differences in animals. It is structured carefully so that directions can be followed easily. Note that alternative answers to the question under investigation are suggested: either the differences across species or the differences across breeds are greater; the problem for pupils is to find data to support one of the two possibilities—an easy task even for the slow learner.

Now let us examine a second activity suggested in connection with the unit "How Animals Behave." In this activity, the pupils are asked to select a category under which observations of animals might be collected—moving-about behaviors, courting, nesting, taking care of the young, and signaling. First the pupil must decide which category and what questions he will seek to answer about that category. Here, we will be concerned only with the "moving-about" behaviors of animals. A pupil might ask, "What is the effect of temperature change upon behavior? Do animals move faster or slower when the temperature rises?" To find the answer, the pupil must vary temperature conditions, choosing animals such as ladybugs, earthworms, or ants, which would be easy to collect and work with. He must plan and construct a temperature box, perhaps heating one end with an electric bulb while the other is left at room temperature or chilled by a tray of ice cubes. Next he must put the animals into the center of the box and observe their behavior. Then he must use his observations and those of his classmates to discover key concepts about moving-about behaviors, checking out the particular variable he has selected for testing and perhaps noting other variables worthy of trying out.

Note that this activity is not structured step by step for the pupil. He is not given a choice of hypotheses for testing; he must use his logical reasoning powers to figure out what is worthy of testing. Nor is he told what to do to test his hypotheses; the plan for experimentation will be a product of his own creativity.

Such an activity can provide the challenge to which bright pupils respond. When they first begin to do independent experimentation, they will need help. The teacher must teach them the process—how to select the variable for testing, how to set up adequate controls, and how to collect data.

To summarize, activities and experiments that place a high premium on logical reasoning and creativity must be provided for gifted pupils. Enough

help should be given so that they do not flounder, but they should be allowed independence in working out solutions to problems.

School Organization and Individual Differences

In recent years many innovations in the organization of the elementary school have been effected to take care of individual differences. Nongrading, team teaching, and dual-progress plans are three such innovations. No attempt will be made here to weigh the advantages and disadvantages of each plan; we will merely point out implications of each plan for the teaching of science.

In the nongraded school, grade labels are removed, and children are assigned to a teacher according to reading level. Thus one teacher of 8-year-old children might have an accelerated class capable of reading fourth grade books, while another, with a slow-moving section, might have pupils reading at the second grade level. Homogeneous grouping, whether on the basis of intelligence test scores or reading ability, has always had an appeal for teachers; teaching would be so much easier and more effective "if only individual differences could be taken care of by some kind of administrative device." Unfortunately (or fortunately, depending upon one's viewpoint), they cannot be. In an accelerated class of 8-year-olds, all the children may be able to read easy fourth grade books, but some can read fifth grade books and some do even better. The teacher must still cope with the problem of providing for those children who are capable of doing more advanced work.

A practical method of obtaining appropriate reading materials is to borrow books on the same subject from higher grades. Many teachers are reluctant to do this for fear that the teacher of the higher grades may say, "But what will they read when they are in *my* room?" The problem is one of coordination within a school so that plans are formulated to enable pupils to encounter challenging materials each year. In many schools, teachers pass along a list of the texts read in one year, so that the next year's teacher can plan realistically. In place of assigning texts according to average reading level, as is commonly done in nongraded schools, a teacher can select texts that will take individual pupils higher on the reading ladder. In place of a single text at one grade level, a teacher will have two or more levels to use with a class. Junior high school texts may be introduced into accelerated classes of twelve-year-olds if the need occurs.

Nongrading is a vertical form of organization of the elementary school; team teaching represents a horizontal form. In some schools, team teaching differs little from departmentalization, with different teachers who work as a team assuming the responsibility for teaching different subjects to the same children. As originally conceived, however, a team consisting of a master teacher and several assistants would be responsible for the instruction of about sixty children. The master teacher in a fourth grade might make a presentation to the whole group or conduct a demonstration, while assistants working with no more than fifteen children would supervise reading assignments and follow-up activities.

Team teaching offers certain advantages for science instruction, particularly in its provision for small-group work. The ratio of one assistant to fifteen pupils means many more opportunities for pupil participation in asking and answering questions and in engaging actively in experiments. Whether or not such opportunities are utilized depends, of course, on careful planning by the team. The practice of giving large group lectures or demonstrations, however, needs to be examined critically. It is a rare teacher, indeed, who can hold the attention of large groups of immature pupils for the length of a science lesson. Where team teaching is in vogue, it is better to confine the whole-group sessions to demonstrations requiring

much time to set up; these sessions should have a fast enough pace to ensure maximum pupil attention.

The dual-progress plan—another plan of organization—organizes the school both horizontally and vertically. For children above the third grade, the day is divided into two parts: graded and nongraded. Pupils spend the graded half of the day with a core teacher who teaches language arts and social studies. During the nongraded half of the day, subject-matter specialists take over, including one for science and arithmetic. For special subjects, children are grouped not according to age or grade, but according to aptitude, interest, and achievement. A fourth grade pupil, for example, if science is one of his strengths, might find himself with older children in the science class. For special subjects in which he is weak, he might find himself with younger children. Thus the plan provides for intraindividual variability—a distinct advantage in teaching a subject such as science where talent may become evident in the intermediate grades. An additional advantage is that the special teacher is usually better prepared in the subject matter and therefore presumably able to do a better job of building concepts.

TEACHING SCIENCE TO CULTURALLY DISADVANTAGED CHILDREN

There are teachers in both rural and urban areas of the United States whose classes consist almost entirely of children of the poor. These children present special learning problems, for their impoverished environment has not provided experiences that help mental structures to develop and intelligence to grow. Their homes lack the toys, books, pencils, paper, and mechanical equipment that offer opportunities for discovery. Their parents, themselves disadvantaged as children, lack the knowledge and skills, as well as the facility with language, to call children's attention to phenomena or to answer questions and raise problems; thus, it is difficult for them to furnish their children with science information and to make the children more curious about the world.

In his day-to-day living, the middle-class child has countless experiences that provide readiness for science. His picture books provide training in observation, sharpened by the mother's comments as she calls attention to details of size, color, shape, and cause-and-effect relationships. He takes a bath and observes floating objects in the tub. He goes for walks with parents who comment on shadows, budding trees, a squirrel's nest, how a woodpecker gets its food, and what the position of the sun in the sky tells us about the approach of suppertime. By the time he enters school, the middle-class child has developed mental structures upon which he can draw for solutions to new problems. The lower-class child, lacking the simple mental structures because of environmental limitations, often cannot grasp the more difficult problems with which he is confronted.

There are three ways in which the teacher can help to compensate for a child's impoverished background. First, the teacher must provide a rich language environment for the child. Language facilitates the development of logical thought. A child who doesn't know the names of domestic animals as common as "cow" is obviously going to have difficulty in learning the concept of "animal." A child who lacks the vocabulary to describe dimensions is not going to be able to deal adequately with the notion that as one dimension gets longer, another gets thinner.

The first two books in *The Macmillan Science Series* are illustrated profusely. The teacher can use the pictures to build vocabulary. The teacher can supply labels not only for objects but also for the properties of the objects—shape, color, texture, size, and weight. The teacher can introduce comparative terms such as "taller than," "heavier than," "darker than." The teacher can teach the terms to describe length, width, depth, weight, and other dimensions. The child who knows the terms is more aware of properties of

objects in his environment, and these can help him progress beyond the stage of sizing up an object in terms of whatever variable stands out perceptually.

Beyond the primary grades, the teacher must continue work on vocabulary development. Interestingly enough, it is not the technical vocabulary (e.g. "atom") that presents a problem (provided, of course, the teacher presents the technical terms with proper background); it is the vocabulary to carry on ordinary life activities, which should have been built during the early years, that is lacking. The child learns "pendulum," but he doesn't know the phrase "back and forth" to describe its movement. Getting children to talk about what is going on as they carry out experiments reveals these deficiencies. To counter this situation, the teacher can supply the terms, have the child use them, and review them in context from time to time.

The second recommendation for teaching science to culturally disadvantaged children is to provide more, not fewer, sensorimotor experiences than for middle-class children. The culturally deprived child cannot learn science solely by reading about it. He does not bring to the written word a reservoir of cognitive structures built up out of firsthand experiences. To understand the physical world, he must act upon it. There are 9-year-old culturally disadvantaged children who are *not* mentally retarded, but who do not know that if someone drops an object into a glass of water, the water level will rise. It is not enough for the child merely to read about the effect of one's actions; the child must experience it firsthand, assimilating information directly from the activity. Thus, in Book 2, if the disadvantaged child is to understand gears, he needs to use an eggbeater (a new experience for most children of that age) and observe how the gears are used to turn the beaters. Even more important, he needs to construct models of physical processes. As he makes and operates the endless belt described on pages 54 and 55, Book 2, he can see how, when one wheel is turned, the belt is made to move. He can see the force of the first moving wheel carried to the second. Such an experience builds the cognitive structures necessary to comprehend how a force is passed from one part of a machine to another part some distance away, and how twisting the belt into a figure eight makes the wheels turn in opposite directions and so changes the direction of the force.

Teachers will find additional activities included in the teaching suggestions at the sides of each page of text. Those involving actual motor activity are particularly appropriate in compensatory education.

The third suggestion for helping disadvantaged children is to build up their background of general information. Even at age 10, these children, in response to questioning, are likely to say that a duck is not a bird because ducks can't fly, and that birds and ducks can't be related because birds don't swim. Children can glean a great deal of general information from attractive picture books that are placed on the science table. One fourth grade child very nicely solved an animal-classification problem on the basis of information assimilated from picture books. As he put it, "I know ducks are birds because I could see in the pictures that there were some things the same, and I figured out that if it's got feathers and wings it's got to be a bird, and it doesn't count if it doesn't fly." In Piaget's language, equilibration occurred; the boy had given up an earlier, erroneous notion and accommodated the new information being assimilated.

Note that in all of the examples cited above there are opportunities for furthering logical development. The teacher can emphasize whole-part relations when discussing pictures with children. Relative terms such as "longer than" and "thinner than" aid children in understanding that a change in one dimension may be compensated for by a change in another, with resulting conservation. Testing of disadvantaged children at the University of Illinois reveals that they are lower on tests of logical development than middle-

class children. Compensatory education must include special attention to ensure the optimum development of logical processes in disadvantaged children.

FIELD STUDIES IN SCIENCE TEACHING

Science becomes meaningful for children only as it helps them interpret their environment. Classrooms, science books, audiovisual materials, and laboratory equipment are not the only means by which this purpose is to be achieved. At best they represent the beginning of the process. Ultimately, what is learned from a science book, a motion picture, or a laboratory demonstration must be applied or used in situations beyond the classroom if it is to have permanent educational value. Field studies are planned learning activities that take place outside the classroom.

Teachers often assume that once a science concept is dealt with in the classroom, pupils will use it on their own for out-of-classroom activities. It is possible that a few may do so, and rather extensively. Some may use the concept on a relatively limited scale. But many of the pupils may never relate the pertinent concepts to the things that are happening about them. For example, in a unit on conservation, pupils may read about ways in which runoff water erodes unprotected soil. They may view a film that shows the process taking place. They may even do a classroom experiment to measure the soil eroded from protected and unprotected surfaces by a measured quantity of runoff water. But what happens when the pupils *leave* the classroom? Do they recognize places where soil is being eroded? Do they suggest ways in which the erosion can be controlled? More important, do they attempt to do something about it? If the science of soil conservation is to become meaningful to pupils, learning about it must extend beyond the classroom into actual situations where the phenomena are taking place.

After considering the question of how science concepts dealing with soil conservation should be made more meaningful to pupils, a teacher might decide that three types of field studies would be appropriate.

One type has to do with locating places in the schoolyard or in nearby spots where soil is being eroded. Before the pupils started on their search, the teacher would alert them to the kinds of evidence that indicate that soil is being eroded. These include soil that has been washed onto sidewalks, roots of trees that have been exposed by the erosion of soil, small gulleys showing that erosion has started, and deltas of soil that have been deposited by water. After pupils had learned how to spot the evidence, they would proceed as a class or in small groups to locate places of erosion in the area. Following the group activity, pupils could be asked to look for other places near their homes and report their findings to the class.

A second type of field study might be to select one of the places where soil erosion is taking place and plan ways of stopping it. Ideally, this should be a place near the school where everyone can take part. Some pupils might undertake individual control projects in their own communities.

A third type of field study might be to visit a place where a planned procedure is being used on a large scale to control soil erosion. This might be a farm, a public park, a housing development, or new highway construction. The persons who are responsible for the plan would answer pupils' questions.

Based upon the above descriptions of three types of field studies having to do with soil erosion, it is reasonable to expect the following educational purposes to be accomplished by such activities:

1. Reinforcement of science concepts taught in the classroom by observing the concepts in action.

2. Development of the habit of viewing the environment in the light of concepts introduced in the classroom.

3. Recognition of situations that represent problems in need of solution.

4. Personal involvement in solving such problems and the development of the required skills.

5. Acquaintance with efforts to deal with such problems.

6. Acquaintance with agencies and people who assume responsibility for the problems in question.

There are a number of matters that must be considered when using field studies in teaching elementary school science.

Background Preparation

Generally, it is desirable to develop the pertinent conceptual background before undertaking a field study. In the above examples, reading about soil erosion and its causes (Book 3, "Our Planet Earth"; Book 6, "Life on the Earth"), viewing a film that shows how the process takes place, performing experiments to determine the effectiveness of plant cover in reducing erosion, and discussing the facts involved would help to build the essential conceptual background for the three field studies. This would give children the "eyes" with which to observe and interpret their observations.

Comprehensiveness of the Field Study

The field study should not be so comprehensive that teachers and pupils "get lost" in carrying it out. In the above examples, there were three distinct, manageable phases involved. Each phase had a specific purpose to accomplish. The first phase had to do with locating places where soil erosion was taking place. The second was the selection of one of these for further study. The third was finding out how other people solve the problem on a larger scale.

Personal Commitment

Wherever possible, the field study should provide for a personal commitment from each pupil. In these studies each pupil was encouraged to locate places where soil erosion was taking place in his neighborhood and to share findings with the class. In addition to work on the class conservation project, individual pupils were encouraged to undertake small-scale control in their own neighborhoods.

Preplanning

Preplanning can pay high dividends in accomplishing the specific purposes of a field study. There are two aspects to preplanning: the teacher's preplanning by himself and the preplanning that the teacher does with his pupils. It is reasonable to assume that preplanning on the part of the teacher would lead to the decision to conduct the three field studies in the sequence described earlier. He would be responsible for planning and making decisions regarding the feasibility of various approaches to each study. He would also have the responsibility for making administrative arrangements. He would then involve his pupils in planning the details.

Prior to the first field study (that of locating places where erosion had taken place), the teacher and pupils would work together in deciding upon the kinds of evidence that they would look for. They would make plans for recording the evidence and indicating the places where the evidence was found. They would plan how to proceed from the classroom to the places they were going to visit. They would plan how the time allotted for the study would be used.

Field Studies as Investigations

Field studies should be carried out as investigations rather than as idle excursions away from school.

To be an investigation, a field study must have a clearly defined purpose. Although children will use many skills, such as those involved in communicating, observing, comparing, classifying, interpreting, and evaluating, the development of these should not become the primary purpose of a field study carried out as an investigation. Its purpose should be to obtain information and/or to solve a problem.

In the first field study on soil erosion, the purpose was to locate places where erosion was taking place. In the second, it was to suggest ways to control erosion in one of the locations. In the third, it was to find out how erosion is controlled on a large scale. The purpose of each investigation should be made clear to all who are involved in it. Each activity in the investigation should relate clearly to its purpose.

Where investigations involve the collection of specific data, plans should be made for recording them in an organized manner. The organization will be determined by the manner in which the data are to be used. For example, if the field study is to locate places where soil is being eroded by runoff water, a decision will have to be made regarding the area to be explored. Suppose it were limited to the school grounds or to a vacant lot near the school or to a three-square-block area adjacent to the school. Before the exploration was begun, a decision would have to be made regarding the method of recording the sites of erosion once they were found. In this case it would be reasonable to use a mapping method. A map would be drawn of the area. The map would be duplicated and each pupil given a copy. As erosion sites were found, they might be located on the map by placing an X at the appropriate spots. Some legend might even be used to indicate how severe the erosion was at the different sites. These data could then be referred to in selecting the one area that would become the test site for the control study.

Where the investigation has to do with solving the erosion problem in one of the places, other methods of recording data might be used. First, a record should be made of the nature and extent of erosion at the selected site. Next, the method by which the erosion is to be checked should be recorded. Finally, the report should be concluded with statements regarding the apparent success of the method used.

Where the investigation has to do with finding out what methods are used to control erosion on a large scale, the data would probably be recorded as answers to a list of questions prepared before the trip was taken to the site. Different pupils might be given the responsibility for obtaining answers to certain of the listed questions. After the answers were obtained, the study would be concluded by a written report that explained a method of controlling soil erosion on a large scale.

Each investigation should culminate in something that represents a record of what was accomplished as a result of the investigation. Investigations should run full cycle, from purpose back to purpose. The findings of the field study should be reported in ways that show how the purpose of the field study was accomplished.

The Size of the Group

Where it is impractical for the entire class to participate in a field study, a similar group of pupils or an individual pupil might conduct the study for the class. Suppose that the problem of transportation to the site where large-scale soil conservation was being practiced precluded the possibility of the entire class's making the trip. The teacher or one of the parents might take one or more pupils to the site. They could obtain answers to the questions that the class had prepared. Arrangements might even be made for them to take pictures to illustrate the various practices. These could be used in making a report to the whole class.

There are various ways in which teachers can learn about the types of field studies that might be

carried out by their pupils. In *Science for Tomorrow's World,* field studies are suggested at appropriate places in the pupil's text and in the Teachers' Annotated Edition:

BOOK 1
Visit a pet shop (p. 99).

BOOK 2
Compare the warm and cool ground outside your school or house (p. 111).

BOOK 3
Visit a planetarium (p. 35).
Plan a trip to a museum (p. 89).
Visit a food market or a farm (p. 219).

BOOK 4
Visit a public library (p. 131).
Visit a fire station (p. 309).
Visit a water purification plant (p. 314).

BOOK 5
Visit a botanical garden (p. 75).
Visit a drug company (p. 163).
Visit a textile factory (p. 208).
Visit a weather station (p. 261).

BOOK 6
Visit an electric utility company (p. 140).
Visit an astronomical observatory (p. 190).
Visit a biome (p. 296).
Visit a zoo (p. 341).

The soil erosion field studies described earlier come from this source. Generally, schools which have detailed courses of study include field studies among the suggested learning activities. *Science and Children,* published by the National Science Teachers Association, 1201 Sixteenth Street, N.W., Washington, D.C., is designed primarily for elementary school teachers. Each issue contains articles that include out-of-classroom activities in elementary science.

Some school systems supply teachers with guides to sites in the community where field studies may be conducted. These guides include such information as:

1. Name of site.
2. Location and directions for reaching it.
3. Age level for which its use is best suited.
4. Science topics to which the use of the site is related.
5. Data which might be obtained at the site.
6. Specimens or materials that could be collected.
7. Times most suitable for visiting.
8. Person with whom arrangements should be made.
9. Special regulations.
10. Safety factors to consider.
11. Evaluation statements made by those who have previously visited the site.

Sometimes good ideas for field studies can be obtained by talking over the problem with other teachers, especially secondary school science teachers. Finally, elementary school teachers should not underrate their own creative imagination in discovering field studies that will add a new dimension to their science teaching.

Evaluating Field Studies

After the field study is completed, it should be evaluated by teacher and pupils. One of the first questions to ask in evaluating a field study is, "Did it accomplish its purpose?" Where it failed, the next pertinent question is, "Why?" The answers to this latter question then become clues to the safeguards that should be exercised in the next field study.

Suppose, on their first soil erosion field study, children failed to find the evidences of soil erosion that had been anticipated by the teacher. This might indicate that the teacher had not done a careful job in selecting the area to be studied. It might mean that the children had not been properly briefed regarding the kinds of evidence for which to look. It might also mean that, for one reason or another, pupils had not observed carefully enough.

Suppose, on their second field study, the plan developed by the pupils did not control the erosion. This might be accounted for by the fact that they had not considered all causative factors and thus had not provided controls for some of them. It might also be that the plan was a good one, but they failed to carry out some phase of it.

Both teachers and pupils experience great disappointment when projects such as field studies do not turn out as expected. Both are tempted to forget the whole thing and to go on to something else. But there is always a reason for things not turning out as expected. To find the reasons and to carry out another study is an equally important educational experience. From it, pupils learn that one must have as many pertinent facts as possible before making his plan, and furthermore that his plan should take all pertinent facts into consideration. Finally, the pupil learns that the study must be carried out in terms of each detail of the plan.

Local Conditions

The use of field studies has to be adapted to local conditions. One local condition has to do with the availability of sites. The soil erosion field studies described earlier are those that could be carried out in most school situations. Even for schools located in cities where there are asphalt-covered playgrounds, the teacher and class should not have to go far from school to find a vacant lot or a small park area where soil is exposed. And wherever soil is exposed, there will be erosion. Somewhere, in practically every community, new buildings or houses are being constructed. Highway construction is taking place across the country. In these places, soil is being exposed to erosion.

Records of Field Studies

A file should be maintained of all completed field studies. The file, prepared by the teacher, might consist of one-page summaries of each field study, supplemented by a copy of one of the better reports written by the pupils. The teacher's summary should include the following information:

1. Purpose of the field study.
2. The science unit to which it is related.
3. The site and person with whom arrangements were made.
4. The number of pupils involved.
5. Persons who assisted with the study.
6. The date the study was begun and the date it was completed.
7. Problems encountered, along with notes as to how each problem was handled.
8. What pupils learned from the study.
9. Points to keep in mind in planning another, similar study.

Records such as these will be helpful not only in future planning of field studies, but also in sharing ideas about field studies with other teachers. The sharing might be in your own school or with many elementary school teachers through an article written for a journal such as *Science and Children*.

USING THE COMMUNITY

There are a number of good reasons why teachers should make maximum use of their communities in teaching science. The ways in which science relates to the lives of people can be effectively demonstrated by activities taking place in the community. In many communities there are people who are uniquely qualified to serve as authoritative sources of scientific information pertaining to many of the topics studied in class. Local institutions such as libraries, museums, planetariums, parks, zoos, and aquariums have been established as sources of information not usually available elsewhere in the community. Finally, through proper use of community resources, the people involved become better acquainted with the educational program of the school and the ways in which teachers are attempting to implement it. This is particularly important in elementary science, because science was not taught in the elementary school when many of the community's adults were pupils themselves.

Environmental Resources

Science teaching should begin with the ongoing experiences of children. It should move to other experiences from which children can gain more sophisticated insights or concepts. Finally, the new concepts should be used to reinterpret aspects of the immediate environment. Science then becomes a way of making the environment more meaningful.

The child's immediate environment is the community in which he lives. It is both a natural environment and a man-made environment. His natural environment includes the sky above him, the nearby woods and fields, streams and ponds, rain, wind, sunlight, clouds, snow, rocks and soil, plants and animals, and other people. His man-made environment includes school buildings and houses; bicycles, automobiles, trucks, tractors, and airplanes; highways, railroads, and streets; telephones, radios, and television; rockets and spacecraft; filling stations and airports; stoves and refrigerators; baseballs and bats; factories and stores; and even merry-go-rounds and Ferris wheels. Such an analysis as the above could be extended almost indefinitely. What is indicated is that the community represents a laboratory with almost unlimited resources for teaching science. In fact, the environmental resources in any community are so extensive that teachers may find it difficult to know where to begin.

Application of Concepts

You could begin by writing the title of each unit in your science text on a separate sheet of paper. Under each title, list the topics that are dealt with in that unit. Next to each topic, list activities in your community that might be used in helping to teach the concepts with which the topic deals. Here is an example of how this might be done for some of the topics in a unit on forces (Book 4, Unit 2):

UNIT: FORCES

Topics	*Community Activities and Objects to Which Concepts Apply:*
Making things move	Men loading a truck by hand; Men shoveling gravel; Hoist used by a construction gang working on a building.

Forces of different sizes	Bulldozer digging a basement for new apartment houses; Car lift at a local filling station; Automatic door-opener at a supermarket.
Measuring forces	Scales used in weighing baggage at an airline terminal; Scales for weighing trucks at inspection stations on highways; Scales for weighing children in the nurse's office; The recorded weight tests of fishing lines sold in a sporting goods store; Testing air pressure in tires at a filling station; Posted load limits on bridges; Posted load limits on elevators; Anemometer at a weather station.
Keeping things from moving	Brakes on automobiles; Prop reversal for slowing down airplanes; Retaining walls on the side of a steep hill; Plant cover to prevent soil erosion.
Balancing forces	Sanding icy streets; Supports on a stepladder; Timber braces in a mine; Supporting trees to protect from high winds; Bicycle stands; Door stops; Umbrella stops; Scaffolding to support workmen.
Forces have direction	Weather vane to indicate direction of winds; Hitting a baseball, a tennis ball, or a golf ball; throwing a baseball or a bowling ball; shooting baskets.

Going faster	Roller coaster; Streamlined cars; Skiing on steep slopes.
Changing directions	Steering wheels on automobiles; Rudders on airplanes; Handlebars on bicycles.

These are only a few local examples of how certain science concepts are applied. As you search for others, many more may be found. Once the searching process is started, pupils should be encouraged to take part. As pupils find additional examples, the meaning of the concept will become more firmly established in their minds.

The Community as a Source of Problems

The community not only provides many examples of how science concepts are being applied, but it is often a source of problems that require science for their solution. Here is an example of how one class became involved in an interesting local problem. At about the time the class had completed their study of a unit on conservation, an editorial dealing with the disposition of unsightly junked car bodies appeared in the local paper. The editorial proposed that the bodies be dumped into one of the Great Lakes—Lake Ontario. According to the editorial, this would remove an eyesore from the landscape and at the same time provide cover at the bottom of the lake for fish. In fact it was reported that local fishermen were in favor of the proposal.

Since pupils in this science class had learned about the importance of conserving metals, such as those used in making car bodies, they felt that the plan would be a waste of mineral resources. They believed it would be much better to reclaim the metal, and so they decided to write to the editor of the paper about their opinions. But their teacher encouraged them to check all of the facts involved in the situation before they wrote the letter.

A clipping of the editorial, along with an explanation of what the science class proposed to do, was sent to the United States Department of the Interior for evaluation. An assistant secretary of the Department replied with a two-page letter. Two paragraphs from his letter are quoted below:

> *With respect to the disposal of automobile bodies, it should be recognized first of all that the major part by weight of a junked car—the chassis—is very largely reclaimed, either for used parts or for steel furnace feed, before the unsightly body shell arrives in a so-called automobile graveyard. These shells have little or no reclamation value for several reasons. First, enormously expensive machinery must be maintained at the waste dealer's yard in order to compact the bulky shell into a form that can be charged into a furnace; second, a serious smog problem is involved in burning out organic material like upholstery before the compacting can take place; and third, the extensive electrical systems in modern automobiles introduce enough copper wiring in the shell to degrade the iron and steel reclaiming in smelting. The net result is the absence, in most instances, of a profit incentive for scrap dealers to reduce automobile bodies to a form saleable to steelmakers in competition with metal derived from cheap and plentiful iron ore.*

Disposal of automobile bodies in the Great Lakes raises other problems. The Department's Fish and Wildlife Service reports that auto bodies have been dumped offshore into salt water apparently without harmful effects, but without much benefit to the fish because the bodies tend to fill with silt and to lose form through rapid rusting. This Service notes, however, that disposal in the fresh water of the Great Lakes poses other objections, in particular, the absorption of the water's oxygen, during the rusting process, from waters already seriously deficient in this gas for the support of valuable aquatic life because of other wastes.

It is quite obvious that both the teacher and his pupils, through becoming involved in this community problem, had their concepts of conservation practices, as well as the science involved, extended considerably beyond the unit on conservation that they had studied. In addition, the pupils learned that one should get all the evidence before making a decision about a problem such as this one. At first the problem appeared to be a relatively simple one, with a clear-cut solution. However, it turned out to be much more complex. Finally, they learned how government agencies, such as the United States Department of the Interior, can be sources of information.

Resource People in the School and Community

In some schools, files are kept of the names and addresses of persons in the local community who may be used as resource persons for various purposes. These generally include teachers and other persons in the school. Where a school does not have such a file, it would be well to start one. A good place to begin would be with those who could be used as resource persons in the elementary science program.

In addition to their professional teaching competence, there often are teachers in school systems who have had other experiences that qualify them to serve as resource persons in elementary science. Included among these would be experiences in outdoor recreational activities such as hunting, fishing, bird watching, stargazing, boating, mountain climbing, and swimming; industries such as farming, manufacturing, lumbering, mining, construction, and transportation; institutions such as hospitals; agencies such as the Forest Service, National Park Service, and Conservation Service; and hobbies such as photography, radio, aviation, and even rocketry. There are people, other than teachers, in the community who have had experiences such as those enumerated above and who may be more available during school time. To find all of them becomes quite a problem. In some schools the P.T.A. takes on the job of locating them. This is generally done by sending out a suitable questionnaire to the patrons of the school. Where such an organized search is not possible, teachers may have to rely upon their pupils and other persons in the school to help locate resource people in the community.

Usually there are a number of professional people in communities who, by virtue of their professions, potentially qualify as resource persons in science. These include scientists, engineers, doctors, and nurses. There are others whose business or work may qualify them as resource persons. These include airplane pilots, firemen, laboratory technicians, food processers, manufacturers, builders, and automotive mechanics. A good way to locate others in this latter category is to examine the classified telephone directory of your community.

Museums as a Community Resource

If your school is located in a community that has a museum, you will surely want to use it as a

resource in your science teaching. Your school may have an inventory of the museum facilities available for school use. If it does, you should examine it to determine which ones would be suitable in your science course. If it doesn't, you can write to the curator of the museum for such information. Here is a partial list of exhibits listed in the general guide to one rather large museum:

Minerals and gems
Fossil fish
Dinosaurs
Ice age mammals
Insects and spiders
Fishes
Amphibians and reptiles
Birds
Mammals
Animal behavior
Man and his origin
The natural history of man
Ecology
North American forests

From a list such as this, you can select the two or three which you think might be worthwhile for your pupils to visit. Next, you should visit the museum to find out more about the exhibits you have selected. When you do this, plan to spend sufficient time to make a reasonably thorough study of each exhibit. Take notes on points of particular interest.

There are two ways in which you can get your pupils to the museum. Probably the best way is to arrange to take them yourself. If you do, have several parents accompany you to assist in supervising the children. Another way is to encourage parents to take their own children. Whichever way is used, some time must be spent in preparing the children for what they are to observe and how they are to observe it. This is where you will make use of the notes taken during your earlier visit to the museum. From these notes, you can prepare a statement regarding the general nature of the exhibits to be visited and how they are related to concepts that pupils have been studying, or will be studying, in science. Specific suggestions of what to look for should be given. These might be formulated as questions to be answered as students observe the exhibit. If you use the question technique, avoid making a large number of detailed questions. Long lists of such questions often result in children's not seeing the forest for the trees. For each selected exhibit, try to decide on the two, three, or four most important ideas with which it deals. Then formulate questions that will highlight the ideas. Regardless of whether you take your pupils or their parents take them, their preparation for the trip will be much the same. It is doubtful that children can experience anything but confusion from an unselective, unplanned, and unstructured trip to a museum. After the museum trip, there should be a time at school for review and summary of what was learned.

Planetariums as a Community Resource

In planetariums, a projector is used to display the movement of heavenly bodies on a hemispherical, or bowl-shaped, ceiling. The projector can be set to show how the heavenly bodies appear to rise in the east, move across the sky, and set in the west. It can also be used to show how the stars appear to an observer on the earth at various locations from the equator to the poles. Methods of locating constellations and prominent stars within them can also be demonstrated.

If there is a planetarium in or near your community, encourage your pupils to attend one of the demonstrations. Obviously this should be done near the time that they are studying about stars and planets in their science class. Since the director changes the planetarium show from time to time, you should try to keep informed about the current shows.

Planetariums usually arrange special showings for school-age children. It might be possible for you to combine a planetarium trip with a museum trip on the same day. As was the case for museum trips, children should be prepared for their visits to the planetarium. Admission fees are usually charged. However, special rates are given for school groups.

Parks as a Community Resource

Parks serve a number of functions in many communities. They are places where people may go for rest and recreation in natural surroundings of trees, shrubs, grass, streams, and ponds. They are places where people may go to learn more about the living things contained within the park. Parks generally contain a greater variety of trees and shrubs than may be found in any other place in the community. They can thus be used by teachers and pupils to observe various types of plant life and to identify similarities and differences among them. Parks can be used in the spring, summer, fall, and winter to demonstrate how the vegetation changes with the change in seasons. Parks usually have ponds or lakes that serve as a refuge for water birds such as ducks and geese. Because they are protected, the birds have become less afraid of people and can be observed from close quarters. Pupils can observe the forms and shapes of their bodies, their eating habits, and the manner in which they walk, fly, and swim.

Zoos as a Community Resource

From the point of view of children, zoos are among the most popular institutions in communities where they are maintained. Children enjoy observing animals. Visits to the zoo can become significant edu cational experiences in science if they are properly planned. In planning a trip to the zoo, teachers need to know what animals are kept there, from where the animals were obtained, and how they are cared for. This information can best be obtained by teachers visiting the zoo and having the educational director give them a conducted tour. For a group of teachers, the director may even include a "behind the scenes" tour of the zoo. On such a tour, teachers will be shown how food for the animals is selected and prepared, how animals are treated for injuries and sickness, how cages are cleaned, and how animals requiring special kinds of environments are protected. With background such as this, teachers can plan the zoo trip with their pupils so that it becomes an integral part of their study of science.

Institutional Aquariums as a Community Resource

Institutional aquariums are more difficult to maintain than zoos and, therefore, are not as common. But where they are maintained, they should be used by teachers to reinforce and extend science concepts related to the variety of living things and how living things are adapted to the environmental conditions in which they are found. The recommended procedures for using a zoo also apply to using an institutional aquarium. Because of the cost of maintaining an aquarium, there is usually an admission fee. As is true for planetariums, special rates are usually given to school groups.

Libraries as a Community Resource

Although firsthand experiences in observing, demonstrating, and experimenting are of paramount importance in learning science concepts and learning the methods of science, we should not leave children with the misconception that these are the only ways of learning about science. Books and periodicals are the most commonly used sources for learning about science. This is as true for the scientist as it is for

the nonscientist. Scientists and science laboratories could not be maintained without good libraries.

It is, therefore, important that the practice of using the library be encouraged, rather than discouraged, while pupils study science in the elementary schools. As evidence of the scientist's point of view regarding the importance of using good science books, the American Association for the Advancement of Science and the National Science Foundation publish bibliographies of science books for children. These bibliographies can be obtained by writing to the American Association for the Advancement of Science, 1515 Massachusetts Avenue, N.W., Washington, D.C., 20005.

Librarians report that a very high proportion of the questions that children bring to them deal with science. To provide for this interest, most libraries maintain a good selection of children's books on science. These books can be used for several purposes. They make it possible for children who want to find out more about certain science topics to do so. They supply information on new developments in science. Some deal with selected science topics in greater depth than is possible in a science textbook. Others present interesting biographies of notable scientists.

One of the best ways of finding out how you can encourage your pupils to use library books in science is to visit the science section of the children's reading room in the library in your community. Acquaint yourself with the wide selection of titles. Take out several books and read them. Then tell your children about the books. If this is done periodically, you can be sure that more and more of the children will begin using the library.

USING AUDIOVISUAL MATERIALS IN SCIENCE TEACHING

A great variety of audiovisual materials is being used in the teaching of science. They range from simple line diagrams drawn on the chalkboard by teachers to elaborate motion pictures that cost thousands of dollars to produce. All are designed to enhance teaching and learning through the use of the visual and/or auditory senses.

Audiovisual materials can be used to show objects, conditions, and events that are not immediately or directly available to pupils, thus extending the range of the pupils' classroom experiences. These may include such subjects as the research work of scientists in Antarctica, the earth as seen from a spacecraft, and conditions at the bottom of the ocean as photographed by a submarine camera.

Audiovisual materials can restructure the time and sequence of pupils' activities and experiences, thus making the activities and experiences more effective for educational purposes. Such materials include tape recordings of interviews, which become reliable records of questions asked by pupils and answers given by an authority on a topic being studied in science; pictures taken to produce reliable records of objects or processes observed during a field trip; pictures of the same child at different ages to show growth changes; slow-motion pictures of activities such as running, in which the sequence of body movements takes place so rapidly that it is difficult to observe the details; or time-lapse movies of events such as the opening of a flower bud, which takes place so slowly it is impossible to observe the details of the marvelous processes involved.

Audiovisual materials may be used to demonstrate procedures and to illustrate concepts in science. They can be used to show how to plan and conduct an experiment, to dissect an animal, to use a piece of apparatus, to prepare exhibits, to conduct a science fair, or to write a report. They can be used as an aid in explaining such concepts as the interdependence of living things, action-reaction, electric currents, work, chemical change, adaptations of living things, and practically any other concept studied in science. Audiovisual materials can be used to organize and

integrate concepts dealing with such topics as weather, nutrition, and spacecraft. They can be used as an aid in visualizing such concepts as the enormous solar system and the minute atom.

Types of Audiovisual Materials

There are two general types of audiovisual materials: those that require special equipment in order to use them and those for which no special equipment is needed. The following audiovisual materials require special equipment, such as cameras, projectors, recorders, microscopes, and phonograph machines:

16 mm. motion picture films
8 mm. motion picture films
filmstrips
2" x 2" slides
prepared microscope slides
large transparencies for overhead projection
recordings, both tape and disk

Among those materials that do not require special equipment are exhibits and models. The remainder of this section will deal with ways in which all of these materials can be used in teaching science.

Motion Pictures

The following list of selected titles, from the catalogue of one of the large producers of educational films, clearly indicates that science subjects are covered extensively by motion pictures and that films are available for every grade level:

FOR KINDERGARTEN AND GRADES 1–3

Animals and Their Foods
Electricity for Beginners
Energy Does Work
How Air Helps Us
How Animals Help Us
How Simple Machines Make Work Easier
Living and Non-Living Things
Rocks: Where They Come From
Sound for Beginners
Winter Comes to the Forest
Zoo Babies
The Big Sun and Our Earth
What Do We See in the Sky?

FOR GRADES 4–6

Air All About Us
Chemical Changes
Color and Light
Energy and Its Forms
Fossils: Clues to Prehistoric Times
Heat and Its Behavior
How Weather Is Forecast
Introducing Atoms and Nuclear Energy
Magnetism
Beyond Our Solar System
Adaptations of Plants and Animals
Fish and Their Characteristics
How Flowers Make Seeds

FOR GRADES 7–9

Airplanes: Principles of Flight
Conserving Our Forests
Electricity: How It Is Generated
Field Trip to a Fish Hatchery
Fire and Oxidation
Electrons and Electronics: An Introduction
Force and Motion
Latitude, Longitude, and Time Zones
Weather: Understanding Storms
Gravity
The Structure of the Earth
Behavior in Animals and Plants
Cell Biology: Life Functions

As is true in selecting any audiovisual material, films should be selected for use in science teaching only when they relate closely to the work at hand.

Furthermore, they should be suitable for the grade level at which they are to be used. Film catalogues carry descriptions of each listed film along with a statement regarding the grade level for which it is best suited. For example, here is a description of the one-reel, eleven-minute color film *Animals and Their Foods* given in the catalogue: "The animals in this film are divided into groups according to the foods they eat: (1) plant eaters; (2) meat eaters; and (3) those that eat both plants and meat. The illustrations explain the basic concept that different animals are suited to eating different kinds of food." Another example is the description for the film entitled *Electricity for Beginners:* "A flashlight that doesn't work leads Frank and Joan to a basic concept: Electricity flows only in a continuous pathway. Simple demonstrations in a hardware store show how electricity can produce heat, light, and magnetism, which in turn can produce motion in a small motor. The film also emphasizes the importance of safety with electricity."

Larger school systems usually maintain an audio-visual center for motion pictures such as those previously discussed. Where this is not the case, films have to be rented from an agency. Under such conditions, teachers often must plan for the use of specific films as much as a year in advance. But it is not always possible to anticipate the exact date upon which a specific topic will be used in a science class. Therefore, the dates for which films are ordered are usually tentative. But the films arrive on the dates ordered and can be kept for only a few days. It is not always possible to coordinate teaching with the prearranged film schedule. When this happens, teachers have to adapt their use of the film to fit the situation. When the film arrives ahead of the time that the topic for which it was selected is being studied, the teacher may find it necessary to use the film as a preview for what is to come in science. When it arrives after the topic has been studied, the teacher may find it advantageous to use the film as a review of the topic.

Much of the success experienced by teachers in using movie films is a direct result of the preparation they make for their use. They select only those films that are related to what they are teaching in science. They read carefully the teaching guide that accompanies the film to become better acquainted with its purpose and content. They preview the film to find out for themselves what it is all about. They prepare a suitable introduction to be used in presenting the film to their pupils. After the film is shown, it is discussed with pupils to make certain that its important points are reviewed and related to the work at hand.

Also available to teachers are 8 mm. cartridge-type film loops, known as single concept films. Such cartridge films require no threading, no rewinding, and only minimal handling. Each cartridge provides about three to five minutes of viewing time, pinpointing and highlighting a single concept. Thus, digestion, the structure of the atom, sound waves, and carbohydrates all might be subjects for the cartridge films. These films, although they do require special, moderately priced projection equipment, are an extremely valuable adjunct to the teaching of a lesson. They enable the teacher to point up a particular aspect of the lesson with ease and clarity.

Filmstrips

There are filmstrips for practically every topic studied in science. Filmstrips have some advantages over movie films. Since they are less expensive, individual schools can have selected collections of them readily available for use in the classroom. It is easy to operate a filmstrip projector. Pupils can participate by asking questions and giving explanations during the time it is being shown. It can easily be reversed to review frames whenever desirable.

Some filmstrips are accompanied by sound records. The sound accompaniment is usually commentary for

each of the frames and must be synchronized with the pictures by the operator of the projector. The accompanying sound commentary covers all important points with which each frame deals. Printed commentaries are also supplied with filmstrips so that the teacher may read as the filmstrip is being shown. The use of a printed commentary gives the teacher the advantage of being able to pace the showing of the filmstrip to accommodate the reactions and questions of the viewers. It is desirable for teachers to preview the filmstrips before classroom use. Furthermore, only those filmstrips that relate closely to the topics being studied should be selected for use.

2" x 2" Slides

These are transparencies whose dimensions are 2 inches by 2 inches. Generally they are color transparencies. Most of the advantages of filmstrips also hold for 2" x 2" slides. Also, while the pictures in a filmstrip are arranged in a definite sequence, it is possible to arrange the 2" x 2" slides into whatever sequence seems appropriate at the time. The 2" x 2" slides have another advantage in that teachers and pupils can take their own pictures with the proper camera and use them to make up their own classroom collection of slides. Here is a list of subjects, each of which could be made into a picture story using 2" x 2" slides:

Seasons in Our Town
Machines Make Work Easier
The Care of Animal Pets
Evidence That Air Is a Substance
Increasing and Decreasing Friction
Evidences of the Water Cycle
Rates at Which Different Seeds Grow
Forces
Units of Measurement

Using the Microscope

The compound microscope is the type most commonly used in classrooms. This microscope has an eyepiece lens and an objective lens, each one magnifying the image of the object to be viewed. Light strikes the mirror near the base of the microscope and then passes through an opening in the stage. The light continues through the objective lens, the tube, and the eyepiece until it reaches the observer's eye.

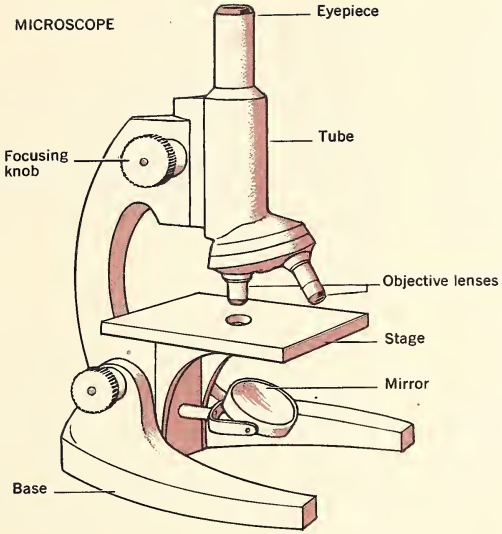
To magnify an object, it is necessary that only a *very thin* segment of the object be used. When magnifying onionskin, for example, use a razor blade to cut and peel off the thinnest possible layer. Place the layer on a glass slide and use a medicine dropper to add one drop of water to the layer. (Note: It is often possible to obtain a better image by using a drop of water-diluted iodine rather than plain water.) Next, place a cover glass over the glass slide.

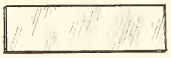
When focusing, place the microscope near a light source such as an open window or a lamp. Adjust the stage so that, when looking through the eyepiece, you see a bright circle of light. Next, with your eye *away* from the eyepiece, slowly turn the focusing knob, lowering the objective lens until it *almost touches* the cover glass. Look again through the eyepiece and slowly turn the focusing knob to *raise* the objective lens. When properly focused, the cells of the onionskin should appear as rectangular, or bricklike, shapes.

Prepared Microscope Slides

As early as the fourth grade, children should be introduced to the microscope. If possible, they should be shown how to prepare slides of living material such as yeast cells, cheek cells, microorganisms in pond water, and the cells of an elodea leaf.

There are limits to how far children can go in preparing their own slides of living material. At the




Glass slide

Cover glass

time that cells are being studied in science, it is desirable to have available a collection of prepared microscope slides of such subjects as paramecia, spirogyra, molds, bacteria, yeast, roots, stems, leaves, flower parts, human bone, human skin, human muscle, and human blood. These slides can be obtained from any biological supply house. Although they cost about $1.00 a slide, they are permanent slides, and with proper care they can be used for a long time.

A microprojector is an instrument that can be used to project the objects on microscope slides onto a sheet of paper. The projected image is enlarged, and it is thus possible for a number of children to see it at the same time. Even though a microprojector is used, children should also have an opportunity to view the slides through a microscope.

Large Transparencies for Overhead Projectors

The overhead projector is operated from the teacher's desk in the front of the classroom. As the teacher operates the projector, he faces the class and the picture is projected on a screen in back of him. Pictures are prepared on a transparent material and may be either black and white or colored. Their size is about 5 inches by 7 inches. As each picture is to be shown, it is placed upon the stage of the projector, where it is visible to the teacher during the time it is projected on the screen. This makes it possible for the teacher to face the class as he talks and to point out any part of the picture to which he wishes to call particular attention. Transparencies may be obtained from scientific supply houses on a number of

topics related to science. A catalogue of one supply house has listed the following series of transparencies for use in elementary science: Human Body Series, Animal Series, Astronomy Series, Atom Series, Geology Series, Meteorology Series, Electricity Series. The Astronomy Series consists of the Solar System, the Sun, Seasons; the Year, Month, and Day; Time Zones; Solar and Lunar Eclipses; Telescopes; and Satellites. This is an overlay series, which means that there is a set of four transparencies for each topic such as the Solar System. As each transparency in the series of four is laid upon the preceding one, it adds information to the ideas that are to be developed by the set.

"Do-it-yourself" kits are available for those who would like to make their own transparencies. The kits can be used to make diagrams, charts, and graphs. They can be produced in black and white or color. The audiovisual departments in some schools have persons skilled in making transparencies produce transparencies for teachers or teach them how to make their own.

Recordings

Both tape and disk recordings can be obtained on various subjects related to science. Some of the titles are listed below:

DISKS

American Bird Songs (an album of 6 records)
Adventures in Sound and Space
Science of Sound

TAPES

Electricity Goes to Work
Galileo Tests a Theory
Van Leeuwenhoek and the Little Animals
How Men Behave
Scientists at Work
Digging Up the Past
The Ocean and Weather
The Rocket Man
Satellite Story

The National Tape Recording Catalogue, published by the Department of Audiovisual Instruction of the National Education Society, lists more than one hundred titles dealing with topics in science. Many of them, such as the ones previously listed here, are appropriate for use in both elementary and junior high school science classes.

Exhibits

One of the most common uses of exhibits in science teaching is the science fair. Where science fairs are noncompetitive and voluntary, they may have very positive educational value. They encourage children to conduct projects of various kinds in coordination with their work in the science classroom. Children are also encouraged to organize the pertinent ideas into forms that are clearly visible. Imagination, creativity, and resourcefulness are applied in preparing science exhibits. In displaying their exhibits, children gain recognition for their efforts. Furthermore, children learn science from the exhibits prepared by other children. At their level, a science fair may serve much the same purpose that scientific meetings serve for the scientist.

In another section of this Teacher's Guide, the use of museum exhibits in teaching science has been discussed. Some museums prepare small exhibits of different kinds that are loaned to schools. These are prepared in glass-covered boxes for display. Generally, a guide book is sent with the exhibits to help the teacher get the most out of them.

Science museums have become quite popular in some of the larger cities. In these museums the exhibits have been prepared to teach people about scientific discoveries and technological inventions. Before a teacher makes a decision to take his class to a science

museum, he should visit the museum to determine which of the exhibits, if any, are related to topics being studied in his science class. If there are none, he probably should not make the effort to take his pupils.

Industrial firms include exhibits of various kinds among their educational materials. Generally, the exhibits are very attractive but deal rather exclusively with products and/or services in which the industry is primarily interested. Teachers should avoid cluttering up their classrooms with any such exhibits that are not closely related to topics being studied. Exhibits that are given to the school, or those that are pupil-made, often introduce storage problems that teachers find difficult to solve.

Posters of various kinds might be classified as exhibits. They can be used for many different purposes in science. Posters can be made to represent graphically such concepts as the water cycle, the oxygen cycle, interdependence of living things, the law of the lever, the conservation of energy, classification systems, the composition of the earth, electric circuits, and many other scientific concepts.

Models

There are many ways in which models can and should be used in teaching science. Often the use of a model is the only way in which the pupil can "get" the idea that the model represents. The globe of the earth, commonly found in classrooms, is a good example of such a model. It would be extremely difficult to think of the earth as a sphere without such a model. Models of the solar system serve a similar purpose. Models of the human skeleton, the brain, the heart, the eye, the ear, and other parts of the body can be used to help children obtain a better understanding of what the inside of the body is like. Models of atoms and molecules can be used to gain a better understanding of the building blocks of nature.

All the models mentioned above can be obtained from scientific supply houses. On the other hand, children can make many of them. If they do, they will probably come to understand the pertinent concepts better than when they use a commercially made model. In making a model of the solar system, children learn much more about comparative sizes and distances than when merely observing a manufactured one. Similarly, when they construct a model crystal, using toothpicks and wax balls, they come to understand the relative positions of atoms in crystals better than when they observe a prepared model. By using clay, pupils can make models of different kinds of cells, craters on the moon, fossils, the ocean floor, volcanoes, the brain, and molecules. Styrofoam balls of assorted sizes have been used in making models of planets and molecules. Cellophane bags can be used in making three-dimensional models of a typical cell. When given the opportunity, children delight in thinking up ways of making models of the different things they study in science. In the "thinking up" process, they are adding new dimensions to their understanding of the concepts.

CREATING INSTRUCTIONAL MATERIALS

In preparing a science program such as *The Macmillan Science Series,* it is impossible to anticipate every kind of learning situation that will confront the teacher in his day-to-day work. Schools vary from one community to the next. Classes within the school vary, as do the children within a particular class. For these reasons, teachers will find it advantageous from time to time to develop supplementary instructional materials adapted to the unique situations that they encounter in their teaching.

Because of the many ways in which learners may come to understand scientific concepts, the teaching of science provides unusual opportunities for teachers to create dynamic instructional materials. The re-

mainder of this section will include suggestions on how a teacher might begin.

Throughout *The Macmillan Science Series,* demonstrations are written into the text to introduce problems or to reinforce concepts. Additional material is suggested in the TAE. There are other ways, too, beyond those suggested in the TAE whereby concepts and their application can be demonstrated. Here are some questions to think about:

1. What are some ways, other than those given in the text, that can be used to demonstrate that air occupies space?

2. How many ways can you show that vibrating objects produce sound?

3. How many examples can you find of the fact that living things are interdependent?

4. In what situations have you witnessed the concept that once a body is set into motion it continues in a straight-line motion of unchanging velocity until acted upon by an unbalanced outside force?

5. In what other ways can you demonstrate diffusion as an example of the movement of molecules of one substance throughout another?

Questions such as these can be asked about every science concept that is demonstrated in your science text. They can serve as guides to "thinking up" or creating additional demonstrations. The more demonstrations or examples of a concept that can be shown to pupils, the better will be their understanding of it.

Creativity can really bloom when applied to the designing of experiments. Detailed descriptions are given for many experiments in the series. This is done to help pupils learn how the various factors in an experiment are handled. It may be that, for some pupils, more experiments of this type should be given, and it is here that the teacher could profitably spend some time in developing additional ones. In some instances it might be advantageous to modify one of the experiments in the text to include different materials and different experimental situations. For example, in an experiment where bread is used to determine the best conditions for mold growth, a variety of organic materials might be used in addition to bread. After observing the results of one such experiment, pupils frequently give the clue to new experiments by asking the question, "I wonder what would happen if this or that were done?"

The golden opportunity for developing new experiments often comes from something that happens during a science lesson. It may come from a searching question asked by one of the pupils. It may come from an unaccountable observation made by someone in the class. It may come when an experiment does not turn out as the class expected because the hypothesis being tested is not a tenable one. The following are examples of how this has happened in different classes.

In one class the teacher was performing a demonstration to show that soil contains air. As the teacher poured water into a large container of soil, bubbles formed at the surface of the soil. The teacher then asked the question, "What do the bubbles indicate?" As expected, one of the pupils replied. "It shows that there is air in the soil." The teacher followed with the question, "What did you observe that supported such a statement?" The pupil responded, "You could see bubbles which proved that air was coming out of the soil." The teacher then asked the class if they agreed. All but one boy did. He asked, "How do you know that the bubbles were formed by air rather than some other gas?" No one could answer the question, and the class now had a problem. How could you prove that the gas coming from the soil when you poured water into it was air? The teacher, working with a small group of pupils, devised a method for capturing the gas that was given

off when water was poured into the soil. They also devised ways of testing the gas to determine if, in fact, it was air.

In a third grade class the pupils had conducted an experiment to determine how temperature affects the growth of mold on bread. They had kept the moistened pieces of bread in small aluminum pans. As they had expected, considerable mold had developed on the bread that had been kept in a warm place. Little or no mold had developed on the pieces of bread that had been kept in the refrigerator. During the time each pupil was examining the bread mold in the pans, one of the pupils held the pan over his head. As he looked up at the bottom of the pan, he saw several tiny holes in it. He asked the teacher what caused them. The teacher commended him for discovering the holes and then asked the class how they could find out what caused the holes in the pan. This led to a series of very interesting activities, including experimentation and the use of several knowledgeable resource persons. Although the teacher and the children were not able to solve the problem through their own experiments, they learned a great deal about the limitations of their own knowledge and abilities and how to use resource people in solving complex problems. Investigation of the problem showed that carbon dioxide from the mold combined with salt from the bread to form sodium carbonate, which caused the holes to form in the aluminum.

In a fifth grade class the pupils had had a number of experiences in heating objects such as iron wire. They had found that heating the objects caused them to expand. The teacher had encouraged the pupils to give other examples from their own experience. Some mentioned that they had seen pictures of steel rails that had expanded on hot summer days and forced the railroad tracks out of shape. Others told of seeing the same thing happen on concrete highways. One girl in the class said she now knew why the drawers in her dresser became stuck in the summer. She explained that the heat expanded the wood so that the drawers became too tight to move in and out easily. Her explanation seemed reasonable to all members of the class. The teacher asked the class, however, if they were sure that wood expanded when heated. This was a good question, since they had done no experiments with wood. The class accepted the challenge to plan an experiment to test the hypothesis that "wood expands when heated."

In planning a method for testing the hypothesis, the children made many suggestions. With the help of the teacher, each suggestion was examined. Finally this plan was accepted: Three holes were bored into a piece of pine board. Then a length of wooden dowel was cut into three equal pieces. It was found convenient to use a one-inch pine board, to make the holes $\frac{3}{8}$ inch in diameter, to get $\frac{3}{8}$-inch dowels, and to make each piece four inches long. Each piece of dowel was numbered, and its hole was given the same number.

The first dowel was then put into an oven and heated at 200° F. for an hour. The second dowel was put into the freezing compartment of a refrigerator for an hour. The third dowel, the control, was left in the room.

At the end of the hour, each dowel was again fitted into its hole in the board. The heated dowel did not expand or stick as was expected, but fit more loosely than it had before it was heated. The cold dowel fit more tightly than before. The dowel that had been left in the room fit in the same way as it had before. The children were amazed. Some of them said, "Our experiment didn't work!" The teacher reassured them that the experiment had worked; it just didn't turn out as they had expected. Now the children really had a problem: If heat doesn't cause dresser drawers to stick in the summer, what does?

The teacher followed up by encouraging them to think of other possible reasons. After a while someone

suggested that it might be that high relative humidity on certain days in the summer caused the drawers to stick. How could this hypothesis be tested? Finally someone hit upon the idea of suspending one of the dowels in a covered jar that had water in the bottom of it. It was explained that the air above the water would soon become filled with water vapor, and the relative humidity would be very high. This seemed reasonable to the class, and so they hung one of the dowels above the water in the covered jar. They left it hanging this way until the next day. When they removed the dowel, they found that it had swollen so that they couldn't even force it into its hole.

As you can see, this experiment took several days to complete. Was it worth the time? This question can only be answered "Yes" if you believe that the creative thinking involved in planning an experiment such as this is important in the education of children.

Picture Stories and Other Supplementary Materials

The picture stories beginning with Book 3 have been used to reinforce concepts developed in the texts by showing how these concepts apply in human activities. There are many possibilities for applying the picture story technique to other concepts in local situations. For example, in Grade 1, where the concept of seasonal changes is introduced, a teacher might prepare a collection of snapshots of the class taken during the different seasons of the year. These could then be arranged in a picture story album or bulletin board display. Such a picture story would incorporate the local climatic conditions in ways that are not possible in a single standardized version of the concept of seasonal changes.

The possibilities for picture stories are practically unlimited. Whenever they are prepared, they should deal clearly with an application of one or more science concepts.

Teachers might also find it worthwhile to prepare supplementary materials for introducing certain units in the text. Bulletin board or large poster displays can be prepared, following the format used in the text. If this is done, the displays can be used to facilitate pupil discussion; they should be designed to help pupils understand better what the unit is about and to make more clear the purposes for studying it.

There may be local situations that relate in unique ways to certain of the units. Where this is so, supplementary materials can be prepared to show the relationship. For example, in communities near the ocean, the unit on oceanography (Book 5) would be introduced quite differently than it would be in communities far removed from the ocean. Because of the climatic differences among communities, units having to do with weather might be introduced in different ways. The unit on conservation (Book 6) would be introduced differently in urban communities than in rural communities. Thus, before undertaking any unit in science, the teacher should investigate possible ways of introducing it so that it relates most closely to the unique experiences of the pupils. When this is done, it will often lead to the development of unit introductory materials to supplement those in the text.

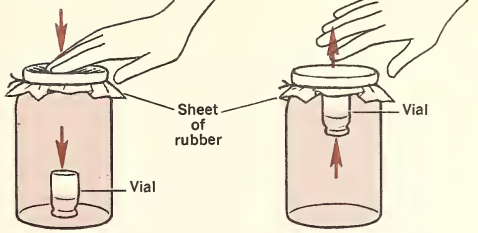
Reviews

One of the many strengths of *Science for Tomorrow's World* is the way in which units are reviewed. Review sections occur frequently and in a variety of interesting forms throughout each book. There are several phases involved in a review of concepts. One phase has to do with *recall* of the facts related to the concepts developed. A second has to do with *relating* the facts to the pertinent concepts. A third has to do with *applying the concept* or using it to explain something. A fourth has to do with using the concept to *predict* what will happen under certain conditions to which the concept applies. In other words, good re-

views provide for practice in identification, interpretation, application, and prediction. Since there are numerous commonly used ways of providing practice with each of these, the creating of new ways is an exciting challenge to any teacher.

Good reviews include the skills and attitudes involved in scientific inquiry. There are several ways of reviewing the skills involved in the planning of an experiment. One way is to present a problem which can be answered by experimentation and to then ask the pupils to plan the experiment. They might do this individually and then write up their plans. They might work in groups of four or five, and each group could then present its plan to the entire class. Or the entire class, with one of the pupils as the leader, might work up the plan. In the latter two instances, all pupils have the opportunity to take part in the evaluation of the planning. Reviews of this sort will be more effective if the teacher gives the students a novel problem—one that is not like any they have worked on before. Another way to provide for review of skills involved in experimentation is to keep a close record of an experiment, noting all pertinent details, including the results and the conclusions. Some of the common errors in experimentation should then be introduced into the record. Give the pupils the experiment as it is written, and ask each of them to evaluate it.

There are many ways in which skill in observation can be practiced through reviews. Demonstrations might be performed and pupils asked to record their observations. Where this is done, the demonstration must call for rather careful observation. One such activity might be the cartesian diver. One cartesian diver demonstration calls for a flat bottle filled with water and covered with rubber sheeting (see diagram). Suspended in the water is an inverted vial that is nearly filled with water. As the rubber sheeting is pressed, the vial goes down. As the pressure is released, the vial rises. The class is asked to tell why the vial went down and then up. The system under observation consists of bottle, water, vial, and hands. Those who have never seen the demonstration before must observe quite carefully to be able to tell that the vial goes down when the hands are pressing the rubber sheeting and that it comes up when the pressure is removed. There are many other demonstrations like this one that teachers could develop and use to give practice in observing.



Here is another example, which has to do with two scientific attitudes—objectivity in evaluating evidence, and reluctance to make a judgment until conclusive evidence has been accumulated. An investigation can be described in which data of both sound and dubious quality are reported. Based upon the evidence, certain conclusions are drawn. Some of the conclusions are consistent with the data, and some go beyond the data. After pupils have read the investigation, they are asked to evaluate the conclusions. What they react to in their evaluations should indicate whether they are weighing evidence and suspending judgment.

In this section we have seen that there are good reasons for teachers to create instructional materials. Through the process, teachers are providing for one of their basic needs, the need to be creative. Consequently, they gain greater satisfaction from their teaching. But more important are the values that come to the pupils who use the materials that the teachers prepare. The learning idiosyncrasies of pupils will be more nearly met, and their relative achievement in learning the concepts and using the methods of scientific inquiry will be improved.

PART IV: OVERVIEWS, TESTS, AND DIRECTORIES

OVERVIEWS OF UNITS IN BOOK 4

This section provides a brief overview of each unit in the book. At the end of the section you will find a listing of the table of contents of each book. This overall table of contents will give you an opportunity to visualize the total program of *Science for Tomorrow's World* and to see the interrelationships of subject matter in the conceptual organization of the series.

Unit One: The Scientist's Way—Comparing Things

Underlying the unit is the endless conflict between the old and the new, personified in Aristotle and Galileo.

Aristotle's approach to explaining natural phenomena was based entirely on observation. Although careful observation is still a foundation of much scientific work today, we now treat conclusions based on observation not as final, but as hypotheses to be tested.

Galileo's radical approach, then, was his insistence on experimentation, to check the hypotheses formed through observation. Galileo's method was also innovative in that it was heavily quantitative. His comparisons were mathematical ones. In the extensive treatment of the pendulum laws given in this unit, we see this quantitative comparison at work. Galileo asked such questions as: "When the length of the string is doubled, what happens?" "When the length of the string is tripled, what happens?" "When the weight is increased, does the swing increase in speed?"

Questions such as these are asked by today's scientists, looking for precise answers to both simple and complex problems.

Unit Two: Understanding Energy

The previous unit of the text set the stage for this unit and those that follow. Pupils are constantly reminded to use controls, and a single experimental factor, in every experiment they perform. Making comparisons should be a constant operation.

In this unit, we are concerned with developing the concept that energy is necessary to do work. In a scientific sense, energy is anything that can be converted into work. Work, within the context of this unit, is mechanical, and we consider the simple machines that do work and require energy. Gravity is introduced in this unit, as a force that produces motion and explains many aspects of work.

At the end of the unit, attention is directed to a study of some impediments to mechanical work.

Unit Three: Living Things—Green Plants

Much of today's information concerning life has been achieved through the study of chemistry. Photosynthesis is now understood in terms of the capture of light energy, permitting the chemical combination of carbon dioxide and water to form glucose. Chemical changes in plants require, store, transfer, and release energy. Energy is a requirement for all life, one that never ceases while life exists. This is the theme to be carried over from the previous unit.

In this unit we study the food-making aspects of green plants and follow this with a study of their needs for survival and for continual growth.

Unit Four: Animals—Simple and Complex

The concepts developed in this unit are concerned with the enormous diversity of animal life on earth and with man's attempts to understand this diversity.

The enormous diversity in the animal world requires a system to organize it for study into a more comprehensible body of information. Scientists have developed such systems, based on various factors such as sex and reproduction habits, symmetry of body parts, habitat, development history, and eating habits. In this unit we confine our classification to the spinal column, and divide all animals into two major groups, those with and those without backbones.

The pathfinder discussed in this unit, Carolus Linnaeus, gave us in the 18th century the beginnings of modern systematics, or taxonomy.

Unit Five: Using Electricity

Electricity for heating, light, and communication plays an important role in our lives. A realistic education for the world of today and tomorrow must include an understanding of electricity and its safe uses for all children, no matter what kind of work they undertake.

By discussion, pictures, and investigation, youngsters develop the concept of electricity as a form of energy—as a way of getting work done.

The unit introduces the child to charges, negative and positive. They learn about the behavior of like and unlike charges. They are led to understand the difference between static and current electricity and the difference between materials that are insulators and those that are conductors. They learn about closed and open circuits and parallel and series circuits. They are shown how to use electricity safely in a variety of instances in their everyday lives.

Unit Six: Sound—A Form of Energy

Much of physics today is centered around the study of wave phenomena. Heat radiation, light, sound, radio, and television follow the laws of wave mechanics. The simplest wave we know is a water wave, and observation of such a wave can be a valuable aid to our understanding of sound waves.

In this section, we are concerned with sound as a vibration of matter.

All types of vibrations have basic properties in common. The most apparent properties are the amplitude (height), the frequency (number per second), and the length of a wave, or single vibration. Most differences between sounds are caused by differences in these properties.

Unit Seven: Light and Sight

Light, the form of energy that makes it possible for us to see, and sight, the act of seeing, are the subjects of this unit. The concept that we see only what reflects light into our eyes is presented, followed by an exploration of how light is reflected.

The second part of the unit is taken up with the physiology of the human eye and with the nature of lenses, including those in eyeglasses. New advances in eye surgery are also discussed.

Unit Eight: Weather in Your Life

The gaseous envelope, or atmosphere, that surrounds our globe is essentially a mixture of nitrogen (77.3%) and oxygen (20.5%), plus small amounts of carbon dioxide, argon, and other gases. At low altitudes the atmosphere contains variable amounts of water vapor.

The air gets cooler as the altitude gets higher, because atmospheric air is heated by convection currents from the warm surface of the earth.

Weather forecasting is based on understanding of the movements and behavior of air masses. To predict what the weather will be tomorrow, the weatherman must extrapolate from the data found for several previous days. Weather satellites, radar and other instruments, and computers are making weather forecasting ever more precise.

Unit Nine: Safety and Science

Nearly 10 million people a year in the United States are involved in accidents, and another 95,000 are killed in them. These figures should give any teacher motivation for good teaching of safety. It has been proven, in industry, that good training in safety procedures does reduce the frequency of accidents. Throughout this unit there are many instances where your teaching may well mean the difference between the happy, productive life of a fourth grader and a life of despair.

SCIENCE FOR TOMORROW'S WORLD: BOOKS 1-6

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TESTS FOR SCIENCE FOR TOMORROW'S WORLD

On the following pages you will find tests for each unit in the book and for the two "Do You Remember?" sections. The Macmillan Company authorizes any teacher using *Science for Tomorrow's World,* Books 1–6, to reproduce *for use in his or her classroom only* the tests in this guide.

Unit 1: The Scientist's Way—Comparing Things

Select the best answer to complete each statement.
Write the letter of the answer in the space at the right.

1. Telling what is different and what is alike is known as making — 1. b
   a. a good report
   b. a comparison
   c. an instrument
2. Scientists use special tools called — 2. b
   a. controls
   b. instruments
   c. experimental factors
3. The distance from one end of a swing to another is called — 3. a
   a. an arc
   b. a circle
   c. a diameter
4. Aristotle was famous for keeping accurate — 4. a
   a. records
   b. dissections
   c. photographs
5. By studying swinging objects, Galileo found out that — 5. b
   a. the time of the swing of the object differed each time
   b. the time of the swing depended on the length of the string
   c. the time of the swing depended on the object's weight
6. One of the first men to seek scientific proof was — 6. c
   a. Joseph Goldberger
   b. William Beebe
   c. Galileo
7. The one thing that you keep different in an experiment is — 7. b
   a. the control
   b. the experimental factor
   c. the comparison
8. You can tell if a glass of air is heavier than a glass of water — 8. a
   a. by using a scale
   b. by using a ruler
   c. by using a stopwatch

9. There are certain things that you always keep the same in an experiment. These things are called
   a. instruments
   b. test tubes
   c. controls

9. ___ ___ **c** ___ ___

10. Scientists are careful to make comparisons when they do their work. One way scientists make comparisons is by
   a. doing experiments
   b. asking a librarian
   c. making a report

10. ___ ___ **a** ___ ___

11. An instrument used to tell whether it is hotter near the door or near the window is called
   a. a scale
   b. a thermometer
   c. a ruler

11. ___ ___ **b** ___ ___

12. An instrument that you can use to find out whether or not boys run faster than girls is called
   a. a yardstick
   b. a tape measure
   c. a stopwatch

12. ___ ___ **c** ___ ___

13. An instrument that is used to tell which is the thickest book on the teacher's desk is called a
   a. scientific experiment
   b. ruler
   c. balance scale

13. ___ ___ **b** ___ ___

14. There are different instruments that you can use to measure water. One of these instruments is called
   a. a timer
   b. a scale
   c. a measuring glass

14. ___ ___ **c** ___ ___

15. Before scientists send a man into space, they do many things. Among these things, scientists are sure to
   a. watch many television programs
   b. make many speeches
   c. do many experiments

15. ___ ___ **c** ___ ___

16-20. List five important things necessary to do an experiment.

16-20. ___ ___ ___ ___ ___ **(See p. 12 of text.)**

Unit 2: Understanding Energy

Fill in the words that complete the sentences.

1. Machines use energy to do _____. **(work)**
2. Most of the energy in our world comes from the _____. **(sun)**
3. The energy that makes objects move is called _____ energy. **(kinetic)**
4. The energy stored in a rubber band is _____ energy. **(potential)**
5. The push or pull of an object is called its _____. **(force)**
6. Energy may be changed or transformed, but not _____. **(destroyed)**
7. When a pitcher throws a baseball, the stored energy of the ball is changed into _____ energy. **(kinetic)**
8. The source of energy in a flashlight is the _____. **(battery)**
9. The bullet in a gun has _____ energy. **(potential)**
10. When the bullet is fired, the bullet has _____ energy. **(kinetic)**
11. A crowbar is a simple machine called a _____. **(lever)**
12. Pulleys are machines that use _____ to lighten work. **(wheels)**
13. A seesaw is an example of a simple machine called a _____. **(lever)**
14. A bicycle is an example of a simple machine called a _____. **(wheel)**
15. The force that has the ability to keep man from flying off the earth into space is called _____. **(gravity)**
16. The _____ of an object is a measure of the force of gravitational pull on that object. **(weight)**
17. The farther something falls, the greater the _____ with which it will hit another object. **(force)**
18. The harder you pump on a swing, the _____ it moves. **(faster)**
19. An example of a simple machine with which you can lift a thing up by pulling down is a _____. **(pulley)**
20. If a seesaw is 12 feet long, and a boy weighing 40 pounds is sitting on one end of it, then his older brother who weighs 80 pounds would have to sit _____ feet from the center to balance the seesaw. **(3)**

Unit 3: *Living Things—Green Plants*

Fill in the words that complete the sentences.

1. An example of a tree that remains green during the winter is the _____. **(pine; or any other evergreen tree)**
2. The leaves and stems of certain plants die during the winter, but the _____ of the plants remain alive. **(roots)**
3. A desert plant that can store water is the _____. **(cactus)**
4. Young plants can be grown during the wintertime in a special house that is called a _____. **(greenhouse)**
5. Plants without chlorophyll are called _____. **(fungi)**
6. Microscopic plants that are capable of restoring nitrogen to the soil are called _____. **(bacteria)**
7. Plants growing where they are not wanted are _____. **(weeds)**
8. The gypsy moth is harmful because its eggs, deposited on fruit trees, develop into _____. **(caterpillars)**
9. Insects harmful to crops are known as _____. **(pests)**
10. The insect that helps the farmer by eating grasshoppers, flies, and mosquitoes is the _____. **(praying mantis)**
11. Sand, clay, and humus, when mixed together, make _____. **(loam)**
12. Humus a material formed from the remains of decayed _____ and _____. **(plants, animals)**
13. For a seed to grow, it needs air, warmth, and _____. **(moisture)**
14. Soil may be enriched by the use of _____. **(fertilizer)**
15. The best time to water the garden is in the _____. **(evening)**
16. The green color of plants is a result of _____. **(chlorophyll)**
17. In photosynthesis, plants combine carbon dioxide and _____. **(water)**
18. The food that green plants produce is called _____. **(glucose)**
19. In photosynthesis, plants capture energy of the _____. **(sun)**
20. Green plants store food in the form of _____. **(starch)**

Unit 4: Animals—Simple and Complex

Mark these sentences **T** *if they are true, and* **F** *if they are false.*

1. Some living things can make their own food. **(T)**
2. There is no difference between plant and animal cells. **(F)**
3. Living things produce other living things like themselves. **(T)**
4. It is always easy to tell plants and animals apart. **(F)**
5. Some animals do not get rid of wastes. **(F)**
6. The ameba is an animal with a backbone. **(F)**
7. Insects and chickens are two animals that both have the same kind of skeletons. **(F)**
8. Grasshoppers breathe through their lungs. **(F)**
9. The hydra breathes through gills. **(F)**
10. Reptiles lay eggs. **(T)**

Fill in the words that complete the sentences.

1. All living things are made up of units called _____. **(cells)**
2. A structure that is possessed only by plant cells is called the_____. **(cell wall)**
3. All energy comes from the _____. **(sun)**
4. One microorganism that has characteristics of both a plant and an animal is the _____. **(euglena)**
5. Green plants make food by _____. **(photosynthesis)**
6. The largest living animal is the _____. **(whale)**
7. Animals that have hair or fur are called _____. **(mammals)**
8. Scientists who study living things are _____. **(biologists)**
9. An animal made of two layers of cells is the _____. **(hydra)**
10. Cells that carry messages are called _____. **(nerve cells)**

Do You Remember?—Units 1, 2, 3, 4

Select the best answer to complete each statement.
Write the letter of the answer in the space at the right.

1. The way in which scientists make comparisons is by — 1. a
   a. doing experiments
   b. making a report
   c. asking a librarian
2. The things you keep the same in an experiment are called — 2. b
   a. instruments
   b. controls
   c. test tubes
3. Scientist use special tools called — 3. c
   a. experimental factors
   b. controls
   c. instruments
4. The distance from one end of a swing to another is called — 4. c
   a. a diameter
   b. a circle
   c. an arc
5. The one thing that you keep different in an experiment is called the — 5. b
   a. controls
   b. experimental factor
   c. comparison
6. A crowbar is an example of a simple machine called a — 6. a
   a. lever
   b. wrench
   c. pulley
7. The force that keeps man from flying off into space is called — 7. b
   a. magnetic force
   b. gravity
   c. kinetic energy
8. A seesaw is an example of a simple machine called a — 8. c
   a. wheel
   b. pulley
   c. lever

9. Most of the energy in our world comes from the — 9. ___ ___ c ___ ___
   a. work we do
   b. food we eat
   c. sun

10. A desert plant that can store water is the — 10. ___ ___ c ___ ___
   a. oak tree
   b. zinnia
   c. cactus

11. The insect that helps the farmer by eating grasshoppers is the — 11. ___ ___ c ___ ___
   a. mosquito
   b. fly
   c. praying mantis

12. Soil may be enriched by the use of — 12. ___ ___ a ___ ___
   a. fertilizer
   b. grass
   c. water

13. The food that green plants produce is called — 13. ___ ___ c ___ ___
   a. health food
   b. chlorophyll
   c. glucose

14. In photosynthesis, the plant captures the energy of — 14. ___ ___ c ___ ___
   a. water
   b. carbon dioxide
   c. sunlight

15. A living thing that is both plant-like and animal-like is — 15. ___ ___ a ___ ___
   a. the euglena
   b. the ameba
   c. the water lily

16. One animal with a backbone is — 16. ___ ___ c ___ ___
   a. an ameba
   b. an earthworm
   c. a chicken

17. All living things are made up of units called — 17. ___ ___ a ___ ___
   a. cells
   b. grams
   c. classes

18. One living thing that can make its own food is
    a. an ameba
    b. a mold
    c. a sunflower

18. __ __ **c** __ __

19. The scientist who made up a system of classification for living things is
    a. Jan Ingen-Housz
    b. Michael Faraday
    c. Carolus Linnaeus

19. __ __ **c** __ __

20. An animal without a backbone is
    a. a chrysamoeba
    b. a salmon
    c. a bluebird

20. __ __ **a** __ __

Fill in the words that complete the sentences.

1. An animal with two layers of cells is a _____. **(hydra)**
2. Animals that have hair or fur are called _____. **(mammals)**
3. Green plants store the food that they do not need immediately in the form of _____. **(starch)**
4. The green color of plants is a result of _____. **(chlorophyll)**
5. Machines use energy to do _____. **(work)**

Unit 5: Using Electricity

Mark these sentences **T** *if they are true, and* **F** *if they are false.*

1. There can be no electricity if there are no electric outlets and plugs, or batteries and wires. **(T)**
2. Atoms contain an equal number of electrons and protons. **(T)**
3. Electrons have a negative charge and are located in the nucleus of the atom. **(F)**
4. Protons have a positive charge and rotate around orbits. **(F)**
5. Atoms gain or lose protons more easily than electrons. **(F)**

6. Oppositely charged objects attract one another. **(T)**

7. Static electricity is electricity that flows. **(F)**

8. Lightning is a form of static electricity. **(T)**

9. Distance between two oppositely charged objects affects the attraction between them. **(T)**

10. Static electricity can be used to run motors. **(F)**

Select the best answer to complete each statement.
Write the letter of the answer in the space at the right.

1. Which is not true about electricity? 1. **d**
   a. it is used to help light our houses
   b. it is a continuous flow of free electrons
   c. it can easily be carried through copper
   d. it will flow through an open circuit

2. A mercury switch works because 2. **c**
   a. mercury is a magnet
   b. mercury is a good fuel
   c. mercury is a good conductor
   d. mercury is a good insulator

3. When you touch a doorknob and get a shock it is because 3. **d**
   a. there is electricity in the doorknob
   b. current electricity flows up from your shoes
   c. electricity collects in dry air
   d. you have made static electricity

4. When batteries are connected in series, rather than in parallel, a lamp will 4. **a**
   a. burn brighter
   b. burn with the same brightness
   c. not burn at all
   d. cause a short

5. When batteries are connected in parallel, rather than in series, a lamp will 5. **a**
   a. burn longer
   b. burn for a shorter period
   c. not burn at all
   d. cause a short

6. When a fuse burns out you should — 6. d
   a. put new bulbs in lamp sockets
   b. put a penny in the fuse box
   c. put a fuse with a larger number in the fuse box
   d. try to find out what caused the fuse to burn out

7. It is not wise to use electrical things when your hands are wet because — 7. b
   a. you will make them rusty
   b. your skin is a better conductor when it is wet
   c. you will burn out a fuse
   d. your hands are too slippery

8. Lamp cords that are worn are dangerous because — 8. a
   a. electricity can leave the wire where insulation is worn
   b. you might cut yourself
   c. static electricity may be dangerous
   d. the bulb may blow up

9. You should not poke anything into electric outlets because — 9. b
   a. you will break something
   b. you may get a bad shock
   c. you will change the voltage
   d. the light will not burn so brightly

10. If you want Christmas tree lights that will not all go out when one bulb burns out, you should get — 10. d
   a. bigger lights
   b. lights in series
   c. brighter lights
   d. lights in parallel

Unit 6: Sound—A Form of Energy

Fill in the words that complete the sentences.

1. Movements that produce sound are called _____. **(vibrations)**

2. The number of times that an object vibrates in a second is called the object's _____. **(frequency)**

3. Sound moves through the air in the form of _____. **(waves)**

4. A vibrating tuning fork, when it is dipped into water, produces _____ in the water. **(waves)**

5. _____ describes how high or low a sound is. **(pitch)**

6. Without any vibrations, it is not possible for there to be any _____. **(sound)**

7. Sound waves that are bounced back from an object are called _____ waves. **(reflected)**

8. A reflected sound that is heard later than the original sound is called an _____. **(echo)**

9. The "roar" in a sea shell is produced when sound waves are _____ back and forth inside the sea shell. **(reflected)**

10. Soundproofing materials _____ sound waves well. **(absorb)**

Mark these sentences **T** *if they are true, and* **F** *if they are false. If false, write the correct word or words that will make the sentence true.*

1. Sound waves travel *more slowly* through air than when they travel through water. **(T)**

2. The more strongly the sound waves move through the air, the *higher* is the sound. **(F — louder)**

3. The speed of the vibration of an object is what determines the *pitch* of its sound. **(T)**

4. A long string vibrates with a *higher* sound than a short one, provided they both have the same thickness and tension. **(F — lower)**

5. The tightness or looseness of a vibrating string is called its *pitch*. **(F — tension)**

6. Your voice sounds louder in the bathtub because the tiles *absorb* sound waves well. **(F — reflect)**

7. Porous material is material that absorbs *less* sound than solid material. **(F — more)**

8. A *weak* sound produces a soft sound. **(T)**

9. Thickness or thinness of a vibrating object is one of several factors determining *pitch*. **(T)**

10. Draperies help to control noise by *reflecting* sound waves. **(F — absorbing)**

Unit 7: Light and Sight

Fill in the words that complete the sentences.

1. When light bounces off an object, the light is said to be _____ from the object. **(reflected)**

2. When light passes through an object, the object is then said to be _____. **(transparent)**

3. When light cannot pass through an object, the object is then said to be _____. **(opaque)**

4. When light passes through frosted glass, the light is scattered in all directions; therefore the frosted glass is _____. **(translucent)**

5. Dark-colored objects _____ most of the light that hits them. **(absorb)**

6, 7, 8. When light enters your eye, the light must first pass through the _____; the light then passes through _____, which is surrounded by a colored muscle called _____. **(cornea, pupil, iris)**

9, 10. Behind the pupil of the eye is a glass-like structure, called the _____. It can change its shape in order to _____ an object. **(lens, focus)**

11. The speed at which light travels is _____ miles per second. **(186,000)**

12. When light travels through a clear object at a slight angle, the beams of light are _____. **(bent)**

13. The lens focuses the object you see onto the _____, which is at the back of the eyeball. **(retina)**

Mark these sentences **T** *if they are true, and* **F** *if they are false. If false, write the correct word or words that will make the sentence true.*

14. The two types of light receiver cells that make up the retina are called *rods* and *cones*. **(T)**

15. The object appears *right side up* on the back of the eyeball. **(F — upside down)**

16. A person who sees near objects better than objects that are far away is *nearsighted*. **(T)**

17. A person who sees far objects better than objects that are near to him is said to be *farsighted*. **(T)**

18. A person who sees parts of objects blurred or not clear is said to have *asthma*. **(F — astigmatism)**

19. Cryosurgery is one way that is used to restore the sight of people suffering from detached *lenses*. **(F — retinas)**

20. An area on the retina having only cones is called the *fovea*. **(T)**

Unit 8: Weather in Your Life

Fill in the words that complete the sentences.

1, 2, 3. Weather is influenced by changes in _____, _____, and _____. **(temperature; pressure; humidity, or water vapor)**

4. Moving air is called _____. **(wind)**

5. The layers of the air that surround the earth are called the earth's _____. **(atmosphere)**

Mark these sentences **T** *if they are true, and* **F** *if they are false. If false, write the word or words that will make the sentence true.*

1. Warm air is *heavier* than cold air. **(F — lighter)**

2. When air is cooled, its molecules move *closer* together. **(T)**

3. Cold air rushing in through a window into a warm room will *rise* to the *ceiling* of the room. **(F — fall to the floor)**

4. Air over a lake heats more *rapidly* than air over land. **(F — slowly)**

5. The earth acts as a radiator, because it *absorbs* the heat energy from the sun. **(F — radiates)**

6. The air over the water becomes warmer at *night*. **(T)**

7. An anemometer is used to measure the *direction* of the wind. **(F — speed)**

8. Because *gravity* pulls air toward earth, air has weight. **(T)**

9. A barometer measures air *temperature*. **(F — pressure)**
10. *Condensation* is the change of liquid water to water vapor. **(F — evaporation)**

Circle the correct word.

1. Air over water heats up more **(quickly, slowly)** than air over land.
2. A white object absorbs **(more, less)** heat than a black object.

3, 4, 5. During the day, air will move from the **(ocean, land)** toward the **(ocean, land)**, forming a **(land, ocean)** breeze.

Unit 9: Safety and Science

Mark these sentences **T** *if they are true, and* **F** *if they are false.*

1. You should not ride your bicycle "against the traffic." **(T)**
2. It is not necessary to signal turns when riding a bicycle. **(F)**
3. Always ride single file when you are riding with others. **(T)**
4. An eight-sided sign tells the motorist to come to a complete stop. **(T)**

Fill in the words that complete the sentences.

1. Waters that are not safe to use are _____. **(polluted)**
2. One way to remove mud from water is to _____ the water. **(filter)**
3. _____ is put into water to kill germs. **(Chlorine)**
4. Water that has been boiled and condensed to make it pure is called _____ water. **(distilled)**

5, 6, 7. The three things necessary to make a fire are _____, _____, and _____. **(heat, oxygen, fuel)**

8. Always use a _____ to hold a test tube over a fire. **(forceps)**
9. You should wait at least _____ _____ after meals, before going into the water. **(one hour)**
10. You should place hot ashes in a _____ container. **(metal)**

Mark these sentences **T** *if they are true, and* **F** *if they are false. If false, write the correct word that will make the sentence true.*

1. *Carbon dioxide* is used on electrical fires because it does not conduct electricity. **(T)**
2. *Water* is used to put out fires of burning wood. **(T)**
3. *Foam* is used to put out fires of burning liquids. **(T)**
4. Always make sure there is a grownup with you when you go swimming. **(T)**
5. Liquid water changes to vapor through *distillation*. **(F — evaporation)**

Do You Remember?—Units 5, 6, 7, 8, 9

Select the best answer to complete each statement. Write the letter of the answer in the space at the right.

1. Fuses prevent — 1. **b**
   a. magnetic fields
   b. the overloading of a circuit
   c. static electricity
2. Current electricity — 2. **c**
   a. will flow through an open circuit
   b. cannot run motors
   c. is a continuous flow of free electrons
3. When you touch a doorknob after walking across a rug, and you get a shock, — 3. **b**
   a. electricity collects in dry air
   b. you have made static electricity
   c. current electricity flows up from the floor
4. When a fuse blows out, — 4. **b**
   a. put a fuse with a larger number in its place
   b. find out what caused the fuse to blow out
   c. put a coin in the fuse box
5. A worn electric wire is dangerous because — 5. **a**
   a. electricity can leave the wire at the point it is worn
   b. static electricity is present
   c. you might cut yourself on frayed ends

6. The lights in a train do not all go out when one bulb burns out because
   a. the lights are in series
   b. the lights are in parallel
   c. the lights are made to last a long time

6. b

7. Sound waves bounced back from an object are called
   a. reflected waves
   b. refracted waves
   c. absorbed waves

7. a

8. Draperies control noise by
   a. absorbing sound waves
   b. reflecting sound waves
   c. having no effect on sound waves

8. a

9. Reflected sound that is heard later than the original sound is called
   a. an echo
   b. pitch
   c. vibrations

9. a

10. Movements that produce sound are called
    a. frequencies
    b. pitch
    c. vibrations

10. c

11. The tightness or looseness of a vibrating string is called its
    a. tension
    b. pitch
    c. vibration

11. a

12. When light passes through an object, the object is said to be
    a. opaque
    b. transparent
    c. reflected

12. b

13. Behind the pupil of the eye is the glass-like structure called the
    a. lens
    b. retina
    c. cornea

13. a

14. A person who sees near objects better than far objects is
    a. nearsighted
    b. farsighted
    c. suffering from astigmatism

14. a

15. When light travels through a clear object at a single angle, the beams of light are
    a. bent
    b. in straight lines
    c. in wavy lines

15. — — **a** — —

16. Moving air is called
    a. wind
    b. the atmosphere
    c. humidity

16. — — **a** — —

17. An anemometer is used to measure the speed of the
    a. air pressure
    b. wind
    c. water vapor

17. — — **b** — —

18. A barometer measures air
    a. temperature
    b. pressure
    c. humidity

18. — — **b** — —

19. The layers of air that surround the earth are called the
    a. atmosphere
    b. solar system
    c. orbits

19. — — **a** — —

20. Burning liquids can be extinguished with
    a. a water extinguisher
    b. a fan
    c. a carbon dioxide extinguisher

20. — — **c** — —

Fill in the word that completes each sentence.

1. Electrons have a _____ charge. **(negative)**

2. A long string vibrates with a _____ sound than a short one, provided they are of the same thickness and tension. **(lower)**

3. When light cannot pass through an object, the object is _____. **(opaque)**

4. The earth acts as a radiator because it _____ the heat energy from the sun. **(radiates)**

5. When water is made pure, the process is called _____. **(distillation)**

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Bobbs-Merrill Co., 4300 West 62nd St., Indianapolis, Ind., 46206
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Cambridge University Press, 32 East 57th St., New York, N.Y., 10022
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Encyclopaedia Britannica Press, 425 North Michigan Ave., Chicago, Ill., 60611
Field Enterprises Educational Corp., Merchandise Mart Plaza, Chicago, Ill., 60654
Follett Publishing Co., 1010 West Washington Blvd., Chicago, Ill., 60607
W. H. Freeman and Co., 660 Market St., San Francisco, Calif.
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Golden Press, Inc., 850 3rd Ave., New York, N.Y., 10020
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Grosset & Dunlap, Inc., 1107 Broadway, New York, N.Y., 10010 (Mail orders to 227 East Center St., Kingsport, Tenn., 37660)

C. S. Hammond & Co., 515 Valley St., Maplewood, N.J., 07040

Harcourt, Brace and World, Inc., 750 Third Ave., New York, N.Y., 10017

Harper & Row, Publishers, 49 East 33rd St., New York, N.Y., 10017

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Hastings House, Publishers, Inc., 151 East 50th St., New York, N.Y., 10022

Hawthorn Books, Inc., 70 Fifth Ave., New York, N.Y., 10011

D. C. Heath and Company, 285 Columbus Ave., Boston, Mass.

Holiday House, 8 West 13th St., New York, N.Y., 10011

Holt, Rinehart and Winston, Inc., Publishers, 383 Madison Ave., New York, N.Y., 10017

Horn Book, Inc., 585 Boylston St., Boston, Mass., 02116

Houghton Mifflin Co., 2 Park St., Boston, Mass., 02107

Indiana University Press, Bloomington, Ind.

International Publishers, 381 Park Ave. South, New York, N.Y., 10017

Virginia Kirkus Service, 317 West 4th St., New York, N.Y., 10014

Alfred A. Knopf, Inc., 501 Madison Ave., New York, N.Y., 10022

Lane Book Company, Menlo Park, Calif., 94025 (Distributed by Lippincott in all states east of Idaho, Utah, and Arizona)

Lantern Press, Inc., 257 Park Ave. South, New York, N.Y., 10010

Library Publishers, Inc., 153 North Michigan Ave., Chicago, Ill., 60601

J. B. Lippincott Co., East Washington Sq., Philadelphia, Pa., 19105

Little, Brown and Co., 34 Beacon St., Boston, Mass., 02106

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William Morrow and Co., Inc., 425 Park Ave. South, New York, N.Y., 10016

C. V. Mosby Company, 3207 Washington Blvd., St. Louis, Mo.

National Geographic Society, Department FBJ, 1146 16th St., N.W., Washington, D.C., 20036

National Science Teachers Association, 1201 16th St., N.W., Washington, D.C., 20006

Thomas Nelson & Sons, 18 East 41st St., New York, N.Y., 10017

The New American Library of World Literature, Inc., 501 Madison Ave., New York, N.Y., 10022

New York Graphic Society, 95 East Putnam Ave., Greenwich, Conn., 06830

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Sterling Publishing Co., Inc., 419 Fourth Ave., New York, N.Y., 10016
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University of Minnesota Press, 2307 University Ave., S.E., Minneapolis, Minn., 55414
D. Van Nostrand Co., Inc., 120 Alexander St., Princeton, N.J., 08540
Viking Press, 625 Madison Ave., New York, N.Y., 10022
Franklin Watts, Inc., 575 Lexington Ave., New York, N.Y., 10022
Albert Whitman & Co., 560 West Lake St., Chicago, Ill., 60606
H. W. Wilson Co., 950 University Ave., New York, N.Y., 10052
World Publishing Co., 119 West 57th St., New York, N.Y., 10019

Directory of Film and Filmstrip Sources

1. GUIDES

Audio-Visual Communication Review, published bimonthly by the Department of Audio-Visual Instruction, Washington, D.C.

Blue Book of Audio-Visual Materials (annual), Educational Screen, Inc., 64 E. Lake St., Chicago, Ill.

A Directory of 16mm Film Libraries, U.S. Department of Health, Education and Welfare; U.S. Government Printing Office, Washington, D.C.

Education Film Guide (annual), The H. W. Wilson Co., 950 University Ave., New York, N.Y.

Educators Guide to Free Films (annual), Educators Progress Service, Randolph, Wisc.

Filmstrip Guide (annual), The H. W. Wilson Co., 950 University Ave., New York, N.Y.

Modern Index and Guide to Free Educational Films from Industry (annual), Modern Talking Picture Service, Inc., 3 E. 54th St., New York, N.Y.

U.S. Government Films for Public Educational Use, 1955, Office of Education, U.S. Department of Health, Education and Welfare; U.S. Government Printing Office, Washington, D.C.

U.S. Government Films for Schools and Colleges (annual), United World Films Inc., 1445 Park Ave., New York, N.Y.

2. DISTRIBUTORS OF AUDIO-VISUAL AIDS

American Cancer Society, Inc., 521 W. 57th St., New York, N.Y.

American Heart Association, Inc., Film Library, 44 E. 23rd St., New York, N.Y. (Films also available from local heart associations.)

American Museum of Natural History, Slide Library, Central Park West at 79th St., New York, N.Y.

American Red Cross (Contact nearest American Red Cross chapter.)

Association Films, Inc., 347 Madison Ave., New York, N.Y. (Branch offices in Ridgefield, N.J.; Dallas, Tex.; San Francisco, Calif.; La Grange, Ill.)

Bell Telephone System (Contact local Bell Telephone Co. offices for address of regional distributor; or contact the American Telephone and Telegraph Co., Motion Picture Section, 195 Broadway, New York, N.Y.)

Blackhawk Films, 1235 W. 5th St., Davenport, Ia.

Better Vision Institute, Inc., 230 Park Ave., New York, N.Y.

University of California, University Extension, Educational Film Sales Dept., Los Angeles, Calif.

University of Southern California, Audio-Visual Services, Dept. of Cinema; University Park, Los Angeles, Calif.

National Film Board of Canada, 680 Fifth Ave., Suite 819, New York, N.Y.

Carousel Films, Inc., 1501 Broadway, New York, N.Y.

Churchill-Wexler Film Productions, 801 N. Seward St., Los Angeles, Calif.

Coronet Instructional Films, 65 E. South Water St., Chicago, Ill.

DeKalb Agricultural Assn., Inc., Educational Dept., 310 N. 5th St., DeKalb, Ill.

Walt Disney Productions, Educational Film Div., 500 S. Buena Vista Ave., Burbank, Calif. (Branch office in New York, N.Y.)

E. I. duPont de Nemours & Co., Inc., Motion Picture Distribution, Advertising Dept., Wilmington, Del.

Encyclopaedia Britannica Films, 1150 Wilmette Ave., Wilmette, Ill. (Branch offices in Hollywood, Calif.; Atlanta, Ga.; Skokie, Ill.; New York, N.Y.; Dallas, Tex.; Toronto, Ontario, Canada.)

Educational Testing Service, 20 Nassau St., Princeton, N.J. (Branch office in Los Angeles, Calif.)

Film Associates of California, 11014 Santa Monica Blvd., Los Angeles, Calif.

Handel Film Corp., 6926 Melrose Ave., Los Angeles, Calif.

International Film Bureau, Inc., 57 E. Jackson Blvd., Chicago, Ill. (Branch office in Ottawa, Ontario, Canada.)

Indiana University, Audio-Visual Center, Bloomington, Ind.

Life Magazine Filmstrip Div., Time and Life Bldg., Rockefeller Center, New York, N.Y.

McGraw-Hill Book Company, Inc., Text-Film Dept., 330 W. 42nd St., New York, N.Y.

Michigan Dept. of Conservation, Film Loan Service, Lansing, Mich.

Michigan State University, Co-operative Extension Service. Agricultural Hall, Room 10, East Lansing, Mich.

University of Minnesota, Audio-Visual Education Service, Westbrook Hall, Minneapolis, Minn.

Metropolitan Life Insurance Company, 1 Madison Ave., New York, N.Y. (Offices in San Francisco, Calif. and Ottawa, Ontario, Canada.)

Missouri Conservation Commission, Film Loan Library, Monroe Bldg., Jefferson City, Mo.

Modern Talking Picture Service, Inc., Headquarters Office, 3 E. 54th St., New York, N.Y. (Film libraries in other cities throughout the U.S., including Anchorage, Alaska, and Honolulu, Hawaii.)

University of Nebraska, Bureau of Audio-Visual Aids, Extension Div., Lincoln, Nebr.

NET Film Service, Audio-Visual Center, Indiana University, Bloomington, Indiana

The National Foundation, Public Information Dept., 800 Second Ave., New York, N.Y.

National Tuberculosis Assn., 1790 Broadwav, New York, N.Y. (Films loaned through state and local tuberculosis associations.)

State University of New York, College of Forestry at Syracuse University, Dept. of Forest Extension, Syracuse, N.Y.

Ohio Division of Wildlife, Dept. of Natural Resources, 1500 Dublin Rd., Columbus, Ohio

Oregon State System of Higher Education, Dept. of Visual Instruction, General Extension Division, 131 Coliseum, Corvallis, Ore.

Pennsylvania State University, Audio-Visual Aids Library, University Park, Pa.

Shell Oil Co., Public Relations Dept., 50 W. 50th St., New York, N.Y.

Sterling Movies U.S.A., 100 W. Monroe St., Chicago, Ill.

U.S. Forest Service, Dept. of Interior, Washington 25, D.C. (Contact film library of your state university extension division or regional office of the U.S. Forest Service.)

United World Films, Inc., 1445 Park Ave., New York, N.Y. (Branch offices in Los Angeles, Calif.; Miami, Fla.; Atlanta, Ga.; Chicago, Ill.; Portland, Ore.; Dallas, Tex.)

World Wide Pictures, P.O. Box 1055, Sherman Oaks, Calif.

Directory of Science Materials Supply Houses

American Electronic Laboratories, Inc., 121 N. 75th St., Philadelphia, Pa.

American Hospital Supply Corp., 40–05 168th St., Flushing, Queens, N.Y.; or Evanston, Ill. (blood-typing serums, standard supplies)

American Optical Co., Buffalo, N.Y. (optical instruments)

American Type Culture Collection, 2112 M St., N.W., Washington, D.C. (bacteria)

Bausch & Lomb Optical Co., 635 St. Paul St., Rochester, N.Y. (optical instruments)

James G. Biddle Co., 1316 Arch St., Philadelphia, Pa. (scientific instruments)

Biological Research Products Co., 243 W. Root St., Stockyards Station, Chicago, Ill. (fresh and preserved mammalian specimens and organs)

Burgess Battery Co., Freeport, Ill. (dry cells)

California Biological Service, 1612 W. Glenoaks Blvd., Glendale, Calif.

California Botanical Materials Co., 861 E. Columbia Ave., Pomona, Calif.

Cambosco Scientific Co., 37 Antwerp St., Brighton, Mass.

Carolina Biological Supply Co., Elon College, N.C.

Central Scientific Co., 1700 W. Irving Park Rd., Chicago, Ill.

Chemical Rubber Co., 2310 Superior Ave., Cleveland, Ohio

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Difco Laboratories, Inc., 920 Henry St., Detroit 1, Michigan (reagents, culture media)

Dow Chemical Co., Midland, Mich. (chemicals)

Eastman Kodak Co., 343 State St., Rochester, N.Y. (photographic supplies and equipment)

Edmond Scientific Co., 99 E. Gloucester Pike, Barrington, N.J. (scientific instruments)

Fisher Scientific Co., Forbes Ave., Pittsburgh, Pa. (chemicals, laboratory appliances)

General Biochemicals, Inc., 677 Laboratory Park, Chagrin Falls, Ohio (chemicals)

General Biological Supply House, Inc. (Turtox), 8200 S. Hoyne Ave., Chicago, Ill.

Graf-Apsco Co., 5868 Broadway, Chicago, Ill. (microscopes)

Kimble Glass, P.O. Box 1035, Toledo, Ohio (glassware)
Lederle Laboratories, Div. of American Cyanamid Co., Middletown Rd., Pearl River, N.Y. (chemicals)
E. Leitz, Inc., 468 Park Ave., New York, N.Y. (optical instruments)
Los Angeles Biological Laboratory, Woods Hole, Mass. (living and preserved materials)
Merck & Co., Inc., 126 E. Lincoln Ave., Rahway, N.J. (chemicals)
Monsanto Chemical Co., 1700 S. Second St., St. Louis, Mo. (chemicals)
National Biological Supply Co., Inc., 230 W. Superior St., Chicago, Ill.
National Instruments Laboratories, Inc., 828 Evarts St., N.E., Washington, D.C.
New York Scientific Supply Co., Inc., 28 W. 30th St., New York, N.Y.
Nutritional Biochemicals Corp., 21010 Miles Ave., Cleveland, Ohio (chemicals)
A. J. Nystrom & Co., Inc., 3333 Elston Ave., Chicago, Ill. (charts, models)
Research Scientific Supplies, Inc., 69 W. 23rd St., New York, N.Y. (microscopes, microslides, stains)
E. H. Sargent and Co., 4647 W. Foster Ave., Chicago, Ill.
E. H. Sheldon Equipment Co., 101 Park Ave., Rm. 538, New York, N.Y. (laboratory furniture)
Spitz Laboratories, Yorklyn, Dela. (shadowboxes, plasteria)
Sprague-Dawley, Inc., P.O. Box 2071, Madison, Wisc. (laboratory rats)
Standard Scientific Supply Corp., 808 Broadway, New York, N.Y.
Testa Manufacturing Co., 418 S. Pecan St., Los Angeles, Calif. (microscopes)
Triarch Botanical Products, Ripon, Wisc. (botanical microslides)
United Scientific, Inc., 66 Needham, Newton, Mass. (optical instruments)
Wards Natural Science Establishment, Inc., P.O. Box 1712, Rochester, N.Y.
Welch Scientific Co., 1515 Sedgwick St., Chicago, Ill. (scientific apparatus)

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